Eur J Orthop Surg Traumatol (2016) 26:339–353
DOI 10.1007/s00590-016-1757-z

EXPERT'S OPINION • HIP - FRACTURES

Intertrochanteric fractures: a review of fixation methods

Senthil Nathan Sambandam[1] · Jayadev Chandrasekharan[1] · Varatharaj Mounasamy[2] · Cyril Mauffrey[3]

Received: 24 February 2016 / Accepted: 25 February 2016 / Published online: 30 March 2016

Keywords Trochanteric fractures · Implants choices · Dynamic hip screw · Cephalomedullary nail · Hemiarthroplasty

Introduction

Intertrochanteric fractures are common, and data show that nearly half of the fractures around the hip are intertrochanteric. Intramedullary nail with a cephalomedullary screw or sliding hip screw–plate construct is the standard surgical treatment options chosen by most surgeons, and wide variability on fixation methods and outcomes has been observed. Fracture pattern, bone quality, fixation techniques and few other factors are important to achieve ideal results. In this article, we review various fixation methods in detail.

Dynamic hip screw

This is the most commonly used implant and extensively studied implant for extra-capsular hip fractures (Table 1) [1–20]. It is an extra-medullary fixation device that works on the concept of stabilizing the fracture but allowing controlled collapse of the fracture by allowing the screw to slide in the barrel. Proposed advantages of the device are ease of use, low cost, low blood loss, less reoperation rate and good functional outcome. Surgeons electing to use this implant for patients with intertrochanteric fracture should take into consideration various implant-related and patient-related factors.

Design rationale

Dynamic hip screw constructs have a barrel plate, a lag screw that gains fixation in the femoral head and the cortical screws that fix the plate to the proximal femur. The barrel length varies among different manufactures but in general range from 25 mm (short barrel) to 38 mm (long barrel). DHS plates are also available in various barrel angles ranging from 130° to 150°, but the most commonly used is the 130° barrel plate. The femoral head lag screws have shaft diameter of 8 mm, distal thread length of 22 mm and thread diameter of 12.5 mm. The come in various lengths ranging from 50 to 145 mm based on the manufacturers. The lag screw slides in the barrel, thereby allowing dynamic compression at the fracture site when inserted perpendicular to the fracture line.

Biomechanical data

Biomechanical studies have shown good stability of DHS with static and dynamic loading conditions in cadaveric and surrogate bone models [21–29]. A normal patient weighing 70 kg would place 2.5 times their body weight on their hip while walking amounting to around 2000 newton of loading and 3700 newton while standing. They undergo at least 10,000 cycles of load on the implant in the first 4–6 weeks after surgery. Most biomechanical tests were performed taking into consideration these aspects of

✉ Varatharaj Mounasamy
vmounasa@yahoo.com

[1] Department of Orthopaedics, K.G. Hospital and Postgraduate Medical Institute, Arts College Road, Coimbatore, Tamil Nadu 641018, India

[2] VCU Medical Center, Ambulatory Care Center, 417 North 11th Street, Richmond, VA, USA

[3] Denver health Medical Center, Denver, CO, USA

Table 1 DHS studies

DHS--RCTs																			
Author	Country	Number	Follow up (months)	Cut Out/ Migration	Non Union	Overall Reoperation Rate	Implant removal rate	Fixation failure	Periprosthetic fracture	Factors predicting the failure							Fluoroscopy time	Op. time	Bood loss
										Patient factor				Implant factor	Surgery related factors				
										Mean Age	osteoporesis	Fracture Pattern		Breakage	Loss of Reduction	TAD			
												Stable	Un stable						
Kosygan, 2002, jbjs Br	UK	56	6	2		2				82.8		25	31	0			54+/-1	49+/-13	83.6+/-94.2
Garg,2011, Hip Int	INDIA	39	40					6		64.3		0	39				More than pfna	38	More than pfna
Yang, 2011, JBJS Am.	USA	33	12							77		0	33					78	101
Baumgaertner, 1998, CORR	USA	68	28							79		35	33					23% more surgical time than intramedullary	44% more blood loss than intramedullary. IMHS
McCormack, 2013,Injury	CANADA	86	6			3/86				83		0	86					50.1	
Lunsjo, 2001,Acta Orthop Scand	Sweden	238	12	6	0	2				81		0	238	3				45	200
Saudan, 2002,J Ortho trauma	Switzerland	106	12							83.7	- Intraoperative: operative and fluoroscopy times, the difficulty of the operation, intraoperative complications, and blood loss. Radiologic: fracture healing and failure of fixation. Clinical: pain, social functioning score, and mobility score. No diff. between intramedullary and extramedullary. AO/OTA 31-A1 and A2 -								
Parker, 2012, jbjs	UK	300	12			9				82.4		58	242				30	46	
Little, 2008, Jbjs	UK	98	12		0	1		2		84.2		29	69				0.9mts	40.3	160
Hardy,1998, jbjs	Belgium	50	12	1	1	3				79.5		16	34						
Peyser, 2007, jbjs	Israel	53	12	2	0	1			1	82.5		31	14					51.1mts	223.5
Zou, 2009, J Int Med Res	China	63	12	0	1-unstable	3				65		52	11	2			5+/-2mts	93+/-13	410+/-65
Adams, 2001, J ortho Trauma	UK	197	12	4	0	8			1	80.7		96	101						
Ahrengart, 2001, CORR	Sweden	216	6						2	79		144	72						
Barton, 2010, jbjs	UK	110	12	2		2				83.3		0	110						
Bridle, 1991,jbjsBr	UK	51	6	3-cut, 4-	0			0		82.7		23	28					33.5	141

Table 1 continued

.				migr.															
DHS- NON RCTS																			
K.Matre, 2013, Injury	Norway	1792	36	6	17	142	19	59	5	79.1									
C.Fang, 2014, jbjs(br)	China	177	12	4	4	3	1	13	17 lat. Wall #	83.6		90	87			<25 in 176 patients			
Kuang-Kai Hsueh, 2010,SICOT	china	1150	38	64					25										
Macheras Ga,2013, E.E.X.O.T.	Greece	108	12	5-cut out, 2 migration		6				79			108				47.66 +/- 15.87sec .	42.8+/- 9.74	
I. Saarenpää, 2009,SICOT	Finland	134	12	80		11		2	0			54	80		4				

DHS- Biomechanical																	
Author	country	Number	Stability		Native stiffness-N/mm		age	TAD	Load to failure	BMD	PUSH OUT STRENGTH		TORSIONAL STABILITY		PULL OUT STRENGHT		Torque
			stable	unstble		Post op stiffness.											
Lenich et al,2011,BMC musuloskeletal diorder	Germany	10		10													Clock wise 6Nm, Anti clock wise 5Nm
Lukas weiser,2015, Arch Ortho Trauma Surg.	Germany	6		6	875.4+/-288.4	395+/-116.1	73.2	15.7+/-1.6	2778.2+/-196.8	300.6mg/cm³							
F O' Neill, 2011, jbjs(Br)	Ireland									80-160mg/cm³	80 mg/cm3	160 mg/cm3	80 mg/cm3	160 mg/cm3	80 mg/cm3	160mg/cm3	
											305N	1035N	0.53Nm	1.90Nm	247N	742N	
M.B.Sommers, 2004, J Orthop trauma	USA	11		11	Load cycles to cut out					steoporotic							
					0.8KN	1.0KN	1.2KN	1.4KN									
					34107+/-35418	1136+/-310	96+/-114	10+/-5									
Qiang Luo, Hindawi, 2013	Hong Kong,	5		5	Load-650N,cycle-500 at 1Hz and Displacemets in mm												
					CC	SC	CA	IC	CP								
					5.214+/-3.0652mm	4.65+/-1.9mm	5.55+/-1.53mm	2.3+/-2.09mm	12.48+/-4.243mm								
G.K. Kouvidis JOSR 2009	Greece	5		5					1.45KN for 6,638+/-2,837cycles	osteoporotic							
Mark Windolf Clin Biomechanics	Germany	10							10,OOO CYCLES 1500 N								

Table 1 continued

2009									50% DHHS failed 100% DHS failed						
M.J. Curtis Injury 1994	USA	20					64		1500 to 5000cycl es DHS and Gamma failed at 300 cycles for stable and unstable For unstables table,1.1. 23 mm Gamma & 1.71mm DHS (P<0.02) For subtroch anteric, 1.5 mm Gamma & 3.1mm DHS (P<0.02)						
Jerome M Goffin	UK							Minimum stain in the IC position							
JOR 2013								with FEA							

postoperative mobilization (Table 1). Wiser et al. in a recent study on 12 cadavers noted that DHS can withstand static load up to 2778 newton before it fails and was able to withstand cyclical loading of 1400 newton up to 10,000 cycles at 2 Hz. Another study of DHS showed importance of proper DHS screw placement, and it showed that decentralized position leads to rotational failure in the specimen [21].

Clinical data

Biomechanical studies often reveal that intramedullary fixation is more rigid than DHS. However, clinical studies show contradictory results in favor of DHS, especially with stable intertrochanteric fractures. An often-reported clinical advantage of DHS over nailing is the low incidence of femoral fracture and low reoperations. DHS showed clear advantage over Gamma nail in terms of these complications; however, similar favorable results were not seen with DHS over newer nails (PFNA and InterTAN). A recent meta-analysis by Yu et al. [30] showed that DHS has lower cutout, less intraoperative and postoperative fractures and less reoperations compared to Gamma nail. However, DHS failed to show those advantages over non-Gamma nail (PFNA), which was also similar to the finding in other reports [31, 32]. However, Bhandari et al. [33] noted in a meta-analysis in 2008 that risk of femoral fracture is not a concern with third-generation nails, but their meta-analysis revealed a relative risk of 1.8 times for femoral fracture with newer Gamma nails compared to 4.5 times of risk with older nails. Even though there is significant reduction in the risk of femoral fracture compared to older nails, it was still unacceptably high. Various RCTs have shown similar favorable results with DHS compared to Gamma nail, especially with stable intertrochanteric fractures. Hence, with the available evidence, nailing cannot be routinely recommended for stable intertrochanteric fractures and DHS should be the standard of care for stable intertrochanteric fractures with reasonable bone quality.

Factors predicting failure of DHS

DHS fails by various mechanisms including cutout, implant breakage, nonunion and rarely fracture at the tip of plates. Various factors have been shown to increase the risk of DHS failure.

Patient factor: bone mineral density

Osteoporosis has been shown to be an important factor predisposing to cutout in various biomechanical and clinical studies. Windolf et al. showed high failure of DHS implants in specimen with BMD values around 290 mg/cm^3 [34]. Patient's age, which is a surrogate measure of osteoporosis, has been shown to be a risk factor in a study analyzing 63 cutouts in a cohort of 937 DHS fixation.

Fracture factors

Fracture patterns

DHS has produced consistent good results in stable intertrochanteric fractures. However, few authors have raised concerns about high failure rate associated with DHS use in unstable situation. Sadowski noted a failure rate of 35 % when DHS was used for unstable fractures.

Haidukewych et al. [35] in 2001 reported a failure rate of 56 % when using DHS in patients with reverse oblique fractures. Madsen et al. reported a failure rate of around 34 % with DHS when used for unstable fractures. Biomechanical studies have shown less rigidity when unstable fractures were fixed with DHS and constructs failed earlier with cyclical loading. A recent report in 2014 by Evidence-Based Working Group in Trauma after analyzing all the evidence concluded that failure rates of treatment of unstable trochanteric fractures (AO/OTA 31A3) with a sliding hip screw are too high to recommend its use [36, 37].

Fracture reduction

Haidukewych [38] in his report in 2009 emphasized the importance of proper fracture reduction. He reported that no implant, however strong it may be, can sustain the undue forces on the implant in the setting of poor reduction and nonunion. He also emphasized the importance of bone contact and avoiding over distraction. Carr et al. described various techniques that can be used to achieve good intraoperative reduction. Few authors have emphasized the importance of valgus reduction to avoid varus collapse and screw cutout. Pervez et al. [39] noted significant increase in cutout risk with varus fracture reduction in AP plane. De Brujin [40] showed that poor reduction according to Baumgartner criteria is associated with higher risk of cutout (odds ratio 5.19).

Surgeon factors

The surgeon factors include tip-apex distance (TAD), Parker's ratio, Cleveland zones and Baumgartner fracture-reduction grade.

Baumgartner highlighted the importance of screw position and tip-apex distance [41, 42]. It is the sum of the distance of the lag screw tip from the center in AP and lateral views, and he suggested that risk of cutout increased manifold if the TAD was more than 25 mm. Various authors confirmed their findings. A recent report by Andruszkow [43] specifically looking at the predictors of cutout showed TAD as the most important predictor of cutout, and TAD more than 25 mm is associated with 24 times increase in risk of cutout irrespective of the fracture type. Pervez et al. [39] in their study revealed the Tad was more important than the lag screw position or the fracture reduction. Hsueh et al. [44] in their multivariate analysis of cutout following DHS showed that TAD is more important predictor of cutout than screw position, fracture pattern or fracture reduction.

Parker's ratio has also been shown to be an important predictor of screw cutout. A Parker's ratio of less than 40 % and peripheral placement of the DHS screw have been show to increase the risk of cutout by various authors [40]. Pervez showed that abnormal screw from center ratio (similar to Parker's ratio) is associated with higher cutout risk [39].

Cleveland introduced the concept of screw placement zones. According to Cleveland, the head can be divided into 9 zones based on AP and lateral radiographs. Since then various authors have studied the importance of Cleveland zones in biomechanical setup and clinical setup [25, 27, 40]. Biomechanical studies show that C–C position and I–C position are associated with low cutout risk. Luo et al. [25] in their biomechanics study showed less displacement with CI position. Goffin et al. [27] showed better result with inferior–center position in finite element model even when TAD was more than 25, thereby questioning the practice of over-reliance on TAD.

Hsueh et al. [44] in their clinical study showed that the risk of cutout was highest in the superior 3 zones and lowest in the central zone followed by central–inferior zone. Pervez et al. [39] showed high cutout when the lag screw was anterior in the lateral but failed to mention the zone. De Brujin et al. [40] showed that anterior–inferior and central–inferior positions had favorable results (odds ratio 0.11).

DHS versus DHS blade/DHHS

In order to reduce the risk of failure in osteoporotic patients, a helical blade was designed in the place of DHS lag screw. Helical blade has the proposed theoretical advantages of minimal bone loss, insertion by impaction and better cutout resistance. Various authors have compared the biomechanical properties of helical blade plate to conventional DHS and noted favorable results [19, 21, 24, 29, 34, 45–49]. Sommers et al. in their study on surrogate models showed that helical blade constructs showed better results with 1,00,000 cycles of loading at all test loads (0.8 KN, 1 KN, 1.2 KN and 1.4 KN) [24]. Similar favorable biomechanical results of helical blade design over DHS screw were shown by other authors as well [25, 29, 47, 48]. Fang showed comparable clinical results in his recent matched propensity study involving 355 patients (177 DHS blade and 177 DHS) [19]. They had only two failures with the blade plate group compared to 13 failures in the conventional DHS group. These results are in contrast to other studies comparing blade plate to DHS as most other studies failed to show clinical superiority. Fang et al. attribute their excellent results to the blade plate design they used in patients (DHS blade, Synthes), and they state that the less-than-favorable results in other studies [45, 50] may be due to the different blade design with tapering tip (DHHS, Synthes) used by the previous authors.

Cost

DHS has been shown to be the most cost-effective option for stable AO/OTA type 1 fractures and better option for type 2 fracture and least cost-effective for type 3 because of reoperation rate [51].

Cephalomedullary nails

Cephalomedullary nails are the most commonly used fracture fixation device for intertrochanteric fractures in North America [52]. European studies have also shown increasing trend of cephalomedullary nail usage [18]. Considering the design diversity of nails and conflicting data on their complication rate, it is worth looking at them individually.

Gamma nail

Gamma nail (Stryker Howmedica) was first introduced in 1988 [26]. Since then various design modifications have been done and biomechanical and clinical outcome has been reported [21, 28, 53–65] (Table 2). It has been used in over million patients, and its results vary between different generations of nails.

First-generation Gamma nail

This nail has a proximal diameter of 17 mm, valgus angle of 10°, lag screw diameter of 12 mm and distal static locking screw diameter of 6.5 mm. This has been studied extensively.

Biomechanical studies

Sommers et al. [24] showed that Gamma nail screws (12 mm) sustained more loading cycles before cutout/bending compared to DHS for all dynamic loads tested in polyurethane foam model. Similar results were shown for Gamma nail by Curtis et al. [28] in 20 cadaveric specimens. Rosenblum showed Gamma nail fixation to be a very rigid construct with essentially no strain on the femur with both stable and unstable fractures [65].

Clinical studies

Despite excellent biomechanical results shown by first-generation Gamma nail, various authors have raised concerns about its clinical performance because of high fracture rate [14, 16, 66]. Even though some authors have reported high fracture rate and cutout, most other authors reported good outcome following the use of first-generation Gamma nail, especially in unstable trochanteric fractures (Table 2).

Adverse events

Cutout of the femoral screw is the most common adverse event associated with the use of Gamma nail. The reported cutout was 0–16 %. Next common complication that is more specific for first-generation Gamma nail was femoral fracture reported at 0–5 %. In one of the largest series till date, the reported cutout rate and postoperative fracture rates for first-generation Gamma nail were 1.8 and 0.5 %, respectively [64]. Various authors have reported nail breakage, and it is often quoted to be due to poor reduction and distraction at fracture site causing undue stress on the implant around the proximal lag screw hole [63, 67].

Second-generation Gamma nail

The second-generation Gamma nail proximal diameter was reduced to 16.5, proximal lag screw diameter was reduced to 10 mm, valgus angle was reduced to 4°, and distal static locking screw was changed to 5 mm. Second-generation Gamma nail was reported to have less fracture rate compared to first-generation Gamma nail. Bojan in his large series of 3066 Gamma nails including 933 second-generation Gamma nails noted only one periprosthetic fracture (0.1 %) with the second-generation Gamma nail. Gerri et al. and Efstathopoulos reported 0 % fracture with second Generation gamma nail (TGN, Stryker) in 66 patients and 56 patients, respectively [68, 69].

Table 2 Gamma nail studies

GAMMA --RCTs

Author	Country	Number	Follow up (months)	Cut Out/ Migration	Non Union	Overall Reoperation Rate	Fixation failure	Periprosthetic fracture	Factors predicting the failure							Fluoroscopy time
									Patient factor		Implant factor			Surgery related factors		
									Mean Age	osteoporesis	Fracture Pattern		Breakage	Loss of Reduction	TAD	
											Stable	Un stable				
Adams, 2001, J ortho Trauma	UK	203	12	8		12		4	81.2		111	92				
Ahrengart, 2001, CORR	Sweden	210	6	More cut uot than dhs				5	80.5		107	103				More time, more blood loss.
Barton, 2010, jbjs	UK	100	12	3		3			83.1		0	100				
Bridle, 1991,jbjsBr.	UK	49	6	6, 2 cut out, 4migration	0		0	4	81.9		18	31				Op time: 36; Blood loss: 162
O'Brien, 1995	Canada	52	12						83		30	22	There was no significant difference between the two groups with respect to intraoperative blood loss, days in hospital, time to union and eventual functional outcome. The length of the procedure and fluoroscopy time were longer for the GN group.			
Utrilla, 2004,	Spain	104	12		0			0	80.6		81	23	No diff. In op time , less flouroscopy time in gamma.			
Grave, 2012, Acta ortghop	Belgium, **GAMMA 3**	61	12	2	0				73		18	43	0			
Herrera, 2002	Spain	125	12	5	1	9		SHAFT-4 Gt-19	78.9		19	109		1		OP TIME: 68
Schipper, 2004	Netherland	213	12						82.6		165	48				
Vaquero, 2012	Spain, **G3**	31	12	0	2		3	1	83.5	10	0	31	1	0		TIME: 37+/-10; FLU. TIME: 48sec.

GAMMA- NON RCTS

Author	Country	Number	Follow up (months)	Cut Out/ Migration	Non Union	Overall Reoperation Rate	Implant removal rate	Fixation failure	Periprosthetic fracture	Factors predicting the failure						Fluoroscopy time	Blood loss	AVN	Operation time
										Patient factor			Implant factor	Surgery related factors					
										Mean Age	osteo	Fracture Pattern	Breakag	Loss of	TAD				

Table 2 continued

							e				poresi s	Stable	Un stable	e	Reduction					
I. Saarenpää, 2009,SICOT	Finland	134	12			17		4	2	80		54	80		7					
Christian Kukla,J Trauma. 2001	Austria	1000	41	21	1				16	81.2		161	839	1						
Kristian Bjørgul, *Acta Orthopaedica,* 2007	Norway	554	~12	8	9	52			18	78-81		272	282							
S. G. F. Abram,2013, JbJs(br)	UK	223	~10					12, 1 nail subsidence	7, short nail	81		51	172	3						
Christian von Ru¨den, Arch Orthop Trauma Surg, 2014	Germany, **G3**	453	6	2		12								13						
Bojan *et al., BMC Musculoskeletal Disorders,*	Sweden	3066	12yrs	57	41		22 9		19	81		965	2101						17	
2010																				

Gamma- Biomechanical

Author	**country**	**Number**	**Stability**		**Native stiffness-N/mm**	**age**	**TAD**	**Load to failure**		**BMD**	Stress peak at the nail to blade junction , Skewed value				Torque
			stable	**unstble**							Gamma	Targon	Gliding nail	PFNA	
Lenich et al,2011,BMC musuloskeletal diorder	Germany	10		10											Clock wise 6Nm, Anti clock wise 2Nm
S.F. Rosenbleum, 1992, jbjs	USA	10						Strain on the medial side just prox. to the prox. locking screw at 1200N 50% increase in strain in unstable fracture compared to stable fracture.	Strain Medially just below the LT at 1200N 3 fold increase in strain in unstable fracture compared to stable fracture.						
M.J. Curtis Injury 1994	USA	20				64 yrs		1500 to 5000cycles DHS and Gamma failed at 300 cycles for stable and unstable For unstablestable,1.1.23 mm Gamma & 1.71mm DHS (P<0.02) For subtrochanteric, 1.5 mm Gamma & 3.1mm DHS (P<0.02)							
Peter Helwig, 2009, Injury	Germany										943 MPa /1P	785MPa/-1P	1023 MPa/-1P	902 MPa/-1P	

Third-generation Gamma nail

The third-generation Gamma nail was introduced in 2003, and the major design change is that a dynamic distal locking screw option was added to the nail. Buecking et al. reported only one fracture and one cutout in a series of 80 followed-up patients [70]. Winnock de Grave reported 0 % fracture rate and 0.01 % cutout rate in a cohort of 61 Gamma 3 nail [54]. However, authors like D'Arrigo et al. and Wu et al. reported continuing concern of femoral fracture (2.1 and 5.7 %, respectively) and cutout (5 and 8 %, respectively) with Gamma nail [71, 72].

Proximal femoral nail, Synthes (cephalomedullary nails with two 6.5-mm proximal lag screw)

These second-generation Gamma nails differ from Gamma nail by having two proximal lag screws. The most extensively studied nail of this group is the proximal femoral nail [55, 73–80] (Synthes). Other similar nails of this group are Targon nail, Endovis nail, TSN SAN. Schipper et al. in a biomechanical study studied PFN and noted that design modification could lead to low cutout [81]. Ozkan in a biomechanical study compared PFN to locking plate and noted PFN to have higher failure to load with axial load [76]. Morihara et al. in a comparative study showed PFN to have low complications (no cutout, no Z-effect, no fracture) compared to Gamma nail [79]. Ozkan et al. also reported excellent results with no complications and 100 % healing in a cohort of 15 patients [82]. Herrera et al. have shown excellent results with no periprosthetic fracture risk with PFN compared to Gamma nail [55]. Similar excellent results with very low periprosthetic fracture risk were shown by various other authors Norris et al. [83] in a meta-analysis including 18 studies showed that the periprosthetic risk of PFN is less compared to that of Gamma nail and PFNA. One unique problem with this group of implants has been the Z-effect [84, 85]. Koyuncu report 17.7 % complication in this series of 152 patients with 3 Z-effect, 2 reverse Z-effect and 4 screw cutouts [78].

PFNA

These third-generation Gamma nails differ from Gamma nail by having a proximal blade instead of lag screw. The blade was inserted by impaction, thereby avoiding rotation of femoral head and compaction of bone around the blade and reducing the risk of cutout. Hwang et al. [47] showed that PFNA has much resistance to axial load with correct implant position in the center–center or inferior–center position with load to failure of 4175–4462 newton. Konstantinidis showed that in osteoporotic bone PFN withstood 400 cycles of load at 2100 N and in healthy bone it withstood the same load for 20,000 cycles [86]. Various authors have reported the clinical outcome of PFNA [2, 13, 31, 32, 47, 49, 57, 72, 87–103]. Few authors have reported excellent result with no cutouts even when used for unstable fracture patterns. Periprosthetic rates have also been reported to be less than compared to Gamma nail. Simmermacher in his study on 315 patients with unstable trochanteric fractures treated with PFNA, largest cohort reported until date, had cutout in 6 patients and periprosthetic fracture in 7 patients, which is much less than the complications encountered with DHS in unstable situations [49]. Various meta-analyses have also shown the superiority of PFNA over DHS and Gamma nail with respect to blood loss, operative time and fluoroscopy time. Hence, PFNA has biomechanical advantage over DHS and also has shown favorable clinical results compared to DHS and Gamma nail in unstable fractures and may be a safer alternative to these devices. Hence, surgeons can consider using these newer-generation nails in unstable or potentially unstable fractures expecting a more favorable result.

InterTAN

InterTAN is the fourth-generation nail with trapezoidal proximal nail geometry giving rotational stability and has two proximal lags screws, and it interlocks with each other, thereby achieving primary compression at fracture site at the time of insertion. Few authors have reported the outcome of this nail [71, 90, 104]. Biomechanical studies have shown that these implants are almost twice as strong as contemporary nails with load to failure noted at around 8000 newton by few authors with the central position and 6000 newton for decentralized position. The reported torque resistance was also high at around 3.8 newton/m. Clinical data on this nail are limited. Matre et al. [18] studied this nail in one of the largest RCT series to date from Norway involving 341 patients. They included 191 unstable fractures and noted cutout [105, 106] in 13 patients and periprosthetic fracture in five patients. Overall, reoperation rate was 8 % (28 reoperations). Wu et al. [71] showed similar good results in a cohort of 87 patients with cutout in 1 patient and periprosthetic fracture in 1 patient. With the available biomechanical and clinical evidence, it is safe to say that InterTAN shows promising early results and may prove to be a valuable addition to surgeon's armamentarium.

Hemiarthroplasty for intertrochanteric fracture (Table 3)

Hemiarthroplasty has been proposed as an alternative to internal fixation by few authors for unstable intertrochanteric fracture is frail in elderly patients [97, 105,

Table 3 Hemiarthroplasty for IT fracture

Authors	Level of evidence	Number	Implant/prosthesis group 1	Implant/prosthesis group 2	Outcome
Comparative RCTs					
Emami et al. [108]	Level 2	60	DHS	Bipolar hemiarthroplasty	Better functional status and rom No significant diff in mortality 2 screw cutoff
Kim et al. [105]	Level 2	58	PFN Mathys Medical, Bettlach, Switzerland	Long-stem cementless calcar-replacement HA (Mallory-Head calcar-replacement stem; Biomet, Bridgend, UK	No significant diff in functional outcome Shorter OT time, transfusions, low mortality in IF group 3 Nonunion, 2 cutout and 1 anti-rotation screw breakage I D/L
Stappaerts et al. [107]	Level 2	90	DHS (AO/Asif)	Cemented VDP prosthesis	No significant diff in funct outcome High failure rate in IF-2 cutout and 9 varus redisplacement compared to HA–1 D/L High transfusion rate in HA
Comparative non-RCTs					
Tang et al. [97]	Level 3 RS	$N = 303$	PFNA	HA	No diff in functional outcome less OT time, blood loss, low blood transfusions, low mortality
Broos et al. [110]	Level 3 RS	$N = 287$	DHS	Bipolar prosthesis	No significant diff between both
Bonnevialle et al. [111]	level 2 PS	$N = 247$	Gamma nail	HA and arthroplasty prosthesis	High mechanical complications with internal fixation Better functional outcomes with arthroplasty No diff in mortality
Claes et al. [112]	Level 3 RS	$N = 168$	Ender nail/angle blade plate	Endoprosthesis	Improved walking ability and reduced mechanical complication with arthroplasty
Broos et al. [109]	Level 3 RS	$N = 157$	Ender nail/angle blade plate	Bipolar/long-stem total hip VDP endoprosthesis	No diff in mortality Less OT time blood loss and lower mechanical complications with bipolar
Sinno et al. [113]	Level 3 rs	$N = 102$	DHS 54	HA 48	HA is better in functional outcome and HHS OT time, blood loss and blood transfusions were more in IF group
Kayali et al. [114]	Ps 2-year follow-up	$N = 42$ (HA) $N = 45$ (IF)	DHS	Cone HA	Time to weight bear is early in HA-no d/L. stem migration 10.7 mm More early complications in IF group 7 deaths, 6 cutout, 1 AVN, 3 shortening No significant results in long-term outcome

Table 3 continued

Authors	Level of evidence/number	Complications	Outcome
Noncomparative prospective studies			
Kim et al. [106]	Level 2 $N = 143$ Uncemented bipolar H A	Mean stem subsidence was 3.1 ± 2.4 mm 1 periprosthetic#	Stable fixation of post. Medial fragment essential to prevent stem subsidence
Patil et al. [115]	126 2.92 years Cemented bipolar	1 Dislocation 1 Implant breakage 1 Infection 2 Implant Loosening/osteolysis 2 Nonunion of GT 2 Protrusion	
Cho et al. [116]	35 pt 1 year Bipolar	1 d/l 1 Periprosthetic# 1 Acetabular erosion HHS 75	

107–116]. Most authors recommend it in a select subset of patients with ipsilateral hip osteoarthritis, ipsilateral AVN of the femoral head, inflammatory arthritis, unstable fracture pattern with poor bone quality, neglected fractures and failed internal fixations.

Few randomized controlled trails comparing hemiarthroplasty to internal fixation failed to show any no significant difference in functional outcomes, hospital stay, and time to weight bearing or general complication. Emami et al. [108] compared dynamic hip screw (DHS) and bipolar hemiarthroplasty with 30 patients in each group. The average follow-up is 16.5 weeks with bipolar having better functional status and hip range of movements at final follow-up. There was no significant difference in pain severity between these groups. Stappaerts et al. [107] showed similar results in their comparative study of DHS and hemiarthroplasty and noted that there was no significant difference between two groups in the operating time, wound complication, mortality rate and functional outcome. However, they noticed that blood transfusions rates were higher in the hemiarthroplasty group. Similar favorable result for hemiarthroplasty was shown by other authors in nonracist and prospective studies. However, most studies have follow-up of not more than 2 years. In contrast to these studies with favorable outcomes, Kim et al. [105] in a RCT compared proximal femoral nail and long-stem cementless calcar-replacement prosthesis with 29 patients in each group and noted that patients treated with a proximal femoral nail had a shorter operative time, less blood loss, fewer units of blood transfusion, a lower mortality rate and lower hospital costs compared to those treated with the long-stem cementless calcar-replacement prosthesis. There was no significant difference in the functional outcomes, hospital stay, and time to weight bear and general complications. They concluded that primary hemiarthroplasty for unstable intertrochanteric fracture is associated with higher complication rates and proximal femoral nail provides superior clinical outcomes.

Hence, in the absence of concrete evidence, hemiarthroplasty should be undertaken with caution in carefully selected patient with reduced life expectancy and surgeon should be aware of the increased complexity of doing the hemiarthroplasty in these frail patients because of increased blood loss, poor bone quality, absence of calcar or deficient lateral wall, need for abductor repair and higher incidence of dislocation.

Conclusion

Surgeon dealing with intertrochanteric fractures should be aware of contemporary fixation devices and should select a fixation device taking into consideration patient factors,

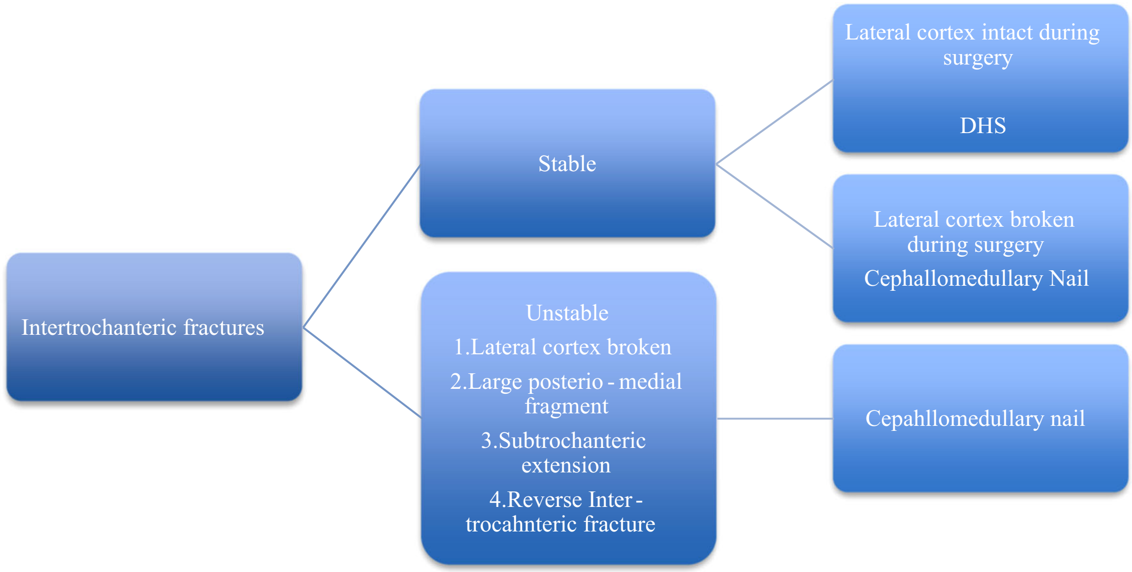

Fig. 1 Flow chart IT

implant factors and fracture factor in a logical evidence-based manner (Fig. 1).

Compliance with ethical standards

Conflict of interest All authors (Senthil Sambandam, Vartharaj Mounasamy, Jayadev Chandrasekharan and Cyril Mauffrey) declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent No human subjects were involved in this study.

References

1. Kosygan KP, Mohan R, Newman RJ (2002) The Gotfried percutaneous compression plate compared with the conventional classic hip screw for the fixation of intertrochanteric fractures of the hip. J Bone Joint Surg Br 84:1922
2. Garg B, Marimuthu K, Kumar V, Malhotra R, Kotwal PP (2011) Outcome of short proximal femoral nail antirotation and dynamic hip screw for fixation of unstable trochanteric fractures. A randomised prospective comparative trial. Hip Int 21:531–536
3. Yang E, Qureshi S, Trokhan S, Joseph D (2011) Gotfried percutaneous compression plating compared with sliding hip screw fixation of intertrochanteric hip fractures: a prospective randomized study. J Bone Joint Surg Am 93:942–947
4. Baumgaertner MR, Curtin SL, Lindskog DM (1998) Intramedullary versus extramedullary fixation for the treatment of intertrochanteric hip fractures. Clin Orthop Relat Res 348:87–94
5. McCormack R, Panagiotopolous K, Buckley R, Penner M, Perey B, Pate G, Goetz T, Piper M (2013) A multicentre, prospective, randomised comparison of the sliding hip screw with the Medoff sliding screw and side plate for unstable intertrochanteric hip fractures. Injury 44:1904–1909
6. Lunsjo K, Ceder L, Thorngren KG, Skytting B, Tidermark J, Berntson PO, Allvin I, Norberg S, Hjalmars K, Larsson S, Knebel R, Hauggaard A, Stigsson L (2001) extramedullary fixation of 569 unstable intertrochanteric fractures: a randomized multicenter trial of the Medoff sliding plate versus three other screw-plate systems. Acta Orthop Scand 72:133–140
7. Saudan M, Lubbeke A, Sadowski C, Riand N, Stern R, Hoffmeyer P (2002) Pertrochanteric fractures: is there an advantage to an intramedullary nail?: a randomized, prospective study of 206 patients comparing the dynamic hip screw and proximal femoral nail. J Orthop Trauma 16:386393
8. Parker MJ, Bowers TR, Pryor GA (2012) Sliding hip screw versus the Targon PF nail in the treatment of trochanteric fractures of the hip: a randomised trial of 600 fractures. J Bone Joint Surg Br 94:391–397
9. Parker MJ, Handoll HH (2010) Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extra capsular hip fractures in adults. Cochrane Database Sits Rev CD000093
10. Little NJ, Verma V, Fernando C, Elliott DS, Khaleel A (2008) A prospective trial comparing the Holland nail with the dynamic hip screw in the treatment of intertrochanteric fractures of the hip. J Bone Joint Surg Br 90:1073–1078
11. Hardy DCR, Descamps P-Y, Krallis P, Fabeck L, Smets P, Bertens CL, Delince PE (1998) Use of an intramedullary hip-screw compared with a compression hip-screw with a plate for intertrochanteric femoral fractures. A prospective, randomized study of one hundred patients. J Bone Joint Surg Am 80(5):618–630
12. Peyser A, Weil YA, Brocke L, Sela Y, Mosheiff R, Mattan Y, Manor O, Liebergall M (2007) A prospective, randomised study comparing the percutaneous compression plate and the compression hip screw for the treatment of intertrochanteric fractures of the hip. J Bone Joint Surg Br 89:1210–1217
13. Zou J, Xu Y, Yang H (2009) A comparison of proximal femoral nail antirotation and dynamic hip screw devices in trochanteric fractures. J Int Med Res 37:1057–1064
14. Adams CI, Robinson CM, Court-Brown CM, McQueen MM (2001) Prospective randomized controlled trial of an intramedullary nail versus dynamic screw and plate for intertrochanteric fractures of the femur. J Orthop Trauma 15:394–400
15. Barton TM, Gleeson R, Topliss C, Greenwood R, Harries WJ, Chesser TJ (2010) a comparison of the long gamma nail with the

sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur: a prospective randomized trial. J Bone Joint Surg Am 92:792–798
16. Bridle SH, Patel AD, Bircher M, Calvert PT (1991) Fixation of intertrochanteric fractures of the femur. A randomised prospective comparison of the gamma nail and the dynamic hip screw. J Bone Joint Surg Br 73:330–334
17. Ahrengart L, Tornkvist H, Fornander P, Thorngren KG, Pasanen L, Wahlstrom P, Honkonen S, Lindgren U (2002) a randomized study of the compression hip screw and Gamma nail in 426 fractures. Clin Orthop Relat Res 401:209–222
18. Matre K, Havelin LI, Gjertsen JE, Vinje T, Espehaug B, Fevang JM (2013) Sliding hip screw versus IM nail in reverse oblique trochanteric and subtrochanteric fractures. A study of 2716 patients in the Norwegian Hip Fracture Register. Injury 44:735–742
19. Fang C, Lau TW, Wong TM, Lee HL, Leung F (2015) Sliding hip screw versus sliding helical blade for intertrochanteric fractures: a propensity score-matched case control study. Bone Joint J 97B:398–404
20. Macheras G, Galanakos S, Koutsostathis S, Kateros K, Karras A, Papadakis S (2013) Unstable pertrochanteric fractures. A comparison of preliminary results using three different methods of fixation, Acta Orthopaedica et Traumatologica Hellenica **64**
21. Lenich A, Bachmeier S, Prantl L, Nerlich M, Hammer J, Mayr E, AlMunajjed AA, Fuchtmeier B (2011) Is the rotation of the femoral head a potential initiation for cutting out? A theoretical and experimental approach. BMC Musculoskeletal Disord 12:79
22. Weiser L, Ruppel AA, Nuchtern JV, Sellenschloh K, Zeichen J, Puschel K, Morlock MM, Lehmann W (2015) Extra- versus intramedullary treatment of pertrochanteric fractures: a biomechanical in vitro study comparing dynamic hip screw and intramedullary nail. Arch Orthop Trauma Surg 135:1101–1106
23. O'Neill F, Condon F, McGloughlin T, Lenehan B, Coffey JC, Walsh M (2011) Dynamic hip screw versus DHS blade: a biomechanical comparison of the fixation achieved by each implant in bone. J Bone Joint Surg Br 93:616–621
24. Sommers MB, Roth C, Hall H, Kam BC, Ehmke LW, Krieg JC, Madey SM, Bottlang M (2004) A laboratory model to evaluate cutout resistance of implants for pertrochanteric fracture fixation. J Orthop Trauma 18(361):368
25. Luo Q, Yuen G, Lau TW, Yeung K, Leung F (2013) A biomechanical study comparing helical blade with screw design for sliding hip fixations of unstable intertrochanteric fractures. ScientificWorldJournal 2013:1–6
26. Kouvidis GK, Sommers MB, Giannoudis PV, Katonis PG, Bottlang M (2009) Comparison of migration behavior between single and dual lag screw implants for intertrochanteric fracture fixation. J Orthop Surg Res 4:16
27. Goffin JM, Pankaj P, Simpson AH (2013) The importance of lag screw position for the stabilization of trochanteric fractures with a sliding hip screw: a subject-specific finite element study. J Orthop Res 31(596–600):28
28. Curtis MJ, Jinnah RH, Wilson V, Cunningham BW (1994) Proximal femoral fractures: a biomechanical study to compare intramedullary and extramedullary fixation. Injury 25:99–104
29. Al-Munajjed AA, Hammer J, Mayr E, Nerlich M, Lenich A (2008) Biomechanical characterisation of osteosyntheses for proximal femur fractures: helical blade versus screw. Stud Health Technol Inform 133:110
30. Yu J, Zhang C, Li L, Kwong JS, Xue L, Zeng X, Tang L, Li Y, Sun X (2015) Internal fixation treatments for intertrochanteric fracture: a systematic review and meta-analysis of randomized evidence. Sci Rep 5:18195
31. Ma KL, Wang X, Luan FJ, Xu HT, Fang Y, Min J, Luan HX, Yang F, Zheng H, He SJ (2014) Proximal femoral nails antirotation, Gamma nails, and dynamic hip screws for fixation of intertrochanteric fractures of femur: a meta-analysis. Orthop Traumatol Surg Res 100:859–866
32. Shen L, Zhang Y, Shen Y, Cui Z (2013) Antirotation proximal femoral nail versus dynamic hip screw for intertrochanteric fractures: a metaanalysis of randomized controlled studies. Orthop Traumatol Surg Res 99:377–383
33. Bhandari M, Schemitsch E, Jonsson A, Zlowodzki M, Haidukewych GJ (2009) Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a metaanalysis. J Orthop Trauma 23:460–464
34. Windolf M, Braunstein V, Dutoit C, Schwieger K (2009) Is a helical shaped implant a superior alternative to the Dynamic Hip Screw for unstable femoral neck fractures? A biomechanical investigation. Clin Biomech 24:59–64
35. Haidukewych GJ, Israel TA, Berry DJ (2001) Reverse obliquity fractures of the intertrochanteric region of the femur. J Bone Joint Surg Am 83A:643–650
36. Kregor PJ, Obremskey WT, Kreder HJ, Swiontkowski MF (2014) Unstable pertrochanteric femoral fractures. J Orthop Trauma 28(Suppl 8):S25–S28
37. Kregor PJ, Obremskey WT, Kreder HJ, Swiontkowski MF, Evidence based orthopaedic trauma working Group (2005) Unstable pertrochanteric femoral fractures. J Orthop Trauma 19:63–66
38. Haidukewych GJ (2009) Intertrochanteric fractures: ten tips to improve results. J Bone Joint Surg Am 91:712–719
39. Pervez H, Parker MJ, Vowler S (2004) Prediction of fixation failure after sliding hip screw fixation. Injury 35:994–998
40. De Bruijn K, den Hartog D, Tuinebreijer W, Roukema G (2012) Reliability of predictors for screw cutout in intertrochanteric hip fractures. J Bone Joint Surg Am 94:1266–1272
41. Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM (1995) The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. J Bone Joint Surg Am 77:1058–1064
42. Baumgaertner MR, Solberg BD (1997) Awareness of tip-apex distance reduces failure of fixation of trochanteric fractures of the hip. J Bone Joint Surg Br 79:969–971
43. Andruszkow H, Frink M, Fromke C, Matityahu A, Zeckey C, Mommsen P, Suntardjo S, Krettek C, Hildebrand F (2012) Tip apex distance, hip screw placement, and neck shaft angle as potential risk factors for cut-out failure of hip screws after surgical treatment of intertrochanteric fractures. Int Orthop 36:2347–2354
44. Hsueh KK, Fang CK, Chen CM, Su YP, Wu HF, Chiu FY (2010) Risk factors in cutout of sliding hip screw in intertrochanteric fractures: an evaluation of 937 patients. Int Orthop 34:1273–1276
45. Fitzpatrick DC, Sheerin DV, Wolf BR, Wuest TK (2011) A randomized, prospective study comparing intertrochanteric hip fracture fixation with the dynamic hip screw and the dynamic helical hip system in a community practice. Iowa Orthop J 31:166–172
46. Huang X, Leung F, Liu M, Chen L, Xu Z, Xiang Z (2014) Is helical blade superior to screw design in terms of cut-out rate for elderly trochanteric fractures? A meta-analysis of randomized controlled trials. Eur J Orthop Surg Traumatol 24:1461–1468
47. Hwang JH, Garg AK, Oh JK, Oh CW, Lee SJ, Myung-Rae C, Kim MK, Kim H (2012) A biomechanical evaluation of proximal femoral nail antirotation with respect to helical blade position in femoral head: a cadaveric study. Indian J Orthop 46:627–632
48. Lenich A, Fierlbeck J, Al-Munajjed A, Dendorfer S, Mai R, Fuchtmeier B, Mayr E, Hammer J (2006) First clinical and biomechanical results of the Trochanteric Fixation Nail (TFN). Technol Health Care 14:403–409

49. Simmermacher RK, Ljungqvist J, Bail H, Hockertz T, Vochteloo AJ, Ochs U, Werken C, Studygroup AP (2008) The new proximal femoral nail antirotation (PFNA) in daily practice: results of a multicentre clinical study. Injury 39:932–939
50. O'Malley NT, Deeb AP, Bingham KW, Kates SL (2012) Outcome of the dynamic helical hip screw system for intertrochanteric hip fractures in the elderly patients. Geriatr Orthop Surg Rehabil 3:68–73
51. Swart E, Makhni EC, Macaulay W, Rosenwasser MP, Bozic KJ (2014) Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. J Bone Joint Surg Am 96:1612–1620
52. Anglen JO, Weinstein JN (2008) Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American board of orthopaedic surgery database. J Bone Joint Surg Am 90:700–707
53. O'Brien PJ, Meek RN, Blachut PA, Broekhuyse HM, Sabharwal S (1995) Fixation of intertrochanteric hip fractures: gamma nail versus dynamic hip screw. A randomized, prospective study. Can J Surg 38:516520
54. Winnock de Grave P, Tampere T, Byn P, Van Overschelde J, Pattyn C, Verdonk R (2012) Intramedullary fixation of intertrochanteric hip fractures: a comparison of two implant designs. A prospective randomised clinical trial. Acta Orthop Belg 78:192–198
55. Herrera A, Domingo LJ, Calvo A, Martinez A, Cuenca J (2002) A comparative study of trochanteric fractures treated with the Gamma nail or the proximal femoral nail. Int Orthop 26:365–369
56. Utrilla AL, Reig JS, Munoz FM, Tufanisco CB (2005) Trochanteric gamma nail and compression hip screw for trochanteric fractures: a randomized, prospective, comparative study in 210 elderly patients with a new design of the gamma nail. J Orthop Trauma 19:229–233
57. Vaquero J, Munoz J, Prat S, Ramirez C, Aguado HJ, Moreno E, Perez MD (2012) Proximal Femoral Nail Antirotation versus Gamma3 nail for intramedullary nailing of unstable trochanteric fractures. A randomised comparative study. Injury 43(Suppl 2):S47–S54
58. Schipper IB, Steyerberg EW, Castelein RM, van der Heijden FH, den Hoed PT, Kerver AJ, van Vugt AB (2004) Treatment of unstable trochanteric fractures. Randomised comparison of the gamma nail and the proximal femoral nail. J Bone Joint Surg Br 86:86–94
59. Kukla C, Heinz T, Gaebler C, Heinze G, Vecsei V (2001) The standard Gamma nail: a critical analysis of 1000 cases. J Trauma 51:77–83
60. Saarenpaa I, Heikkinen T, Ristiniemi J, Hyvonen P, Leppilahti J, Jalovaara P (2009) Functional comparison of the dynamic hip screw and the Gamma locking nail in trochanteric hip fractures: a matched-pair study of 268 patients. Int Orthop 33:255–260
61. Bjorgul K, Reikeras O (2007) Outcome after treatment of complications of Gamma nailing: a prospective study of 554 trochanteric fractures. Acta Orthop 78:231–235
62. Abram SG, Pollard TC, Andrade AJ (2013) Inadequate 'three-point' proximal fixation predicts failure of the Gamma nail. Bone Joint J 95B:825–830
63. von Ruden C, Hungerer S, Augat P, Trapp O, Buhren V, Hierholzer C (2015) Breakage of cephalomedullary nailing in operative treatment of trochanteric and subtrochanteric femoral fractures. Arch Orthop Trauma Surg 135:179–185
64. Bojan AJ, Beimel C, Speitling A, Taglang G, Ekholm C, Jonsson A (2010) 3066 consecutive Gamma Nails. 12 years experience at a single centre. BMC Musculoskelet Disord 11:133
65. Rosenblum SF, Zuckerman JD, Kummer FJ, Tam BS (1992) A biomechanical evaluation of the Gamma nail. J Bone Joint Surg Br 74:352357
66. Butt MS, Krikler SJ, Nafie S, Ali MS (1995) Comparison of dynamic hip screw and gamma nail: a prospective, randomized, controlled trial. Injury 26:615–618
67. Iwakura T, Niikura T, Lee SY, Sakai Y, Nishida K, Kuroda R, Kurosaka M (2013) Breakage of a third generation gamma nail: a case report and review of the literature. Case Rep Orthop 2013:172352
68. Rerri BE, Ayorinde RO, Opadele T, Onayemi B (2011) Short gamma nail fixation for intertrochanteric fractures in the elderly. Eur J Orthop Surg Traumatol 21:275–279
69. Efstathopoulos NE, Nikolaou VS, Lazarettos JT (2007) Intramedullary fixation of intertrochanteric hip fractures: a comparison of two implant designs. Int Orthop 31:71–76
70. Buecking B, Bliemel C, Struewer J, Eschbach D, Ruchholtz S, Muller T (2012) Use of the Gamma3 nail in a teaching hospital for trochanteric fractures: mechanical complications, functional outcomes, and quality of life. BMC Res Notes 5:651
71. Wu D, Ren G, Peng C, Zheng X, Mao F, Zhang Y (2014) InterTan nail versus Gamma3 nail for intramedullary nailing of unstable trochanteric fractures. Diagn Pathol 9:191
72. D'Arrigo C, Carcangiu A, Perugia D, Scapellato S, Alonzo R, Frontini S, Ferretti A (2012) Intertrochanteric fractures: comparison between two different locking nails. Int Orthop 36:2545–2551
73. Karn NK, Jain A, Nepal P, Singh MP, Das N (2011) A prospective randomized control trial comparing proximal femoral nail and sliding hip screw in the management of trochanteric fracture of the femur. Health Renaissance 9:7–11
74. Kumar V, Singh A, Bharti A, Dalmia D, Ali S (2014) A comparison of intramedullary and extramedullary fixation devices in unstable trochanteric fractures. Int J Biomed Adv Res 05:335–339
75. Ozkan K, Cift H, Akan K, Sahin A, Eceviz E, Ugutmen E (2010) Proximal femoral nailing without a fracture table. Eur J Orthop Surg Traumatol 20:229–231
76. Ozkan K, Turkmen I, Sahin A, Yildiz Y, Erturk S, Soylemez MS (2015) A biomechanical comparison of proximal femoral nails and locking proximal anatomic femoral plates in femoral fracture fixation: a study on synthetic bones. Indian J Orthop 49:347–351
77. Korkmaz MF, Erdem MN, Disli Z, Selcuk EB, Karakaplan M, Gogus A (2014) Outcomes of trochanteric femoral fractures treated with proximal femoral nail: an analysis of 100 consecutive cases. Clin Interv Aging 9:569–574
78. Koyuncu S, Altay T, Kayali C, Ozan F, Yamak K (2015) Mechanical failures after fixation with proximal femoral nail and risk factors. Clin Interv Aging 10:1959–1965
79. Morihara T, Arai Y, Tokugawa S, Fujita S, Chatani K, Kubo T (2007) Proximal femoral nail for treatment of trochanteric femoral fractures. J Orthop Surg (Hong Kong) 15:273–277
80. Cheema GS, Rastogi A, Singh V, Goel SC, Mishra D, Arora S (2012) Comparison of cutout resistance of dynamic condylar screw and proximal femoral nail in reverse oblique trochanteric fractures: a biomechanical study. Indian J Orthop 46:259–265
81. Schipper IB, Bresina S, Wahl D, Linke B, Van Vugt AB, Schneider E (2002) Biomechanical evaluation of the proximal femoral nail. Clin Orthop Relat Res 405:277–286
82. Ozkan K, Eceviz E, Unay K, Tasyikan L, Akman B, Eren A (2011) Treatment of reverse oblique trochanteric femoral fractures with proximal femoral nail. Int Orthop 35:595–598
83. Norris R, Bhattacharjee D, Parker MJ (2012) Occurrence of secondary fracture around intramedullary nails used for trochanteric hip fractures: a systematic review of 13,568 patients. Injury 43:706–711
84. Papasimos S, Koutsojannis CM, Panagopoulos A, Megas P, Lambiris E (2005) A randomised comparison of AMBI, TGN and PFN for treatment of unstable trochanteric fractures. Arch Orthop Trauma Surg 125:462–468

85. Pires RE, Santana EO Jr, Santos LE, Giordano V, Balbachevsky D, Dos Reis FB (2011) Failure of fixation of trochanteric femur fractures: clinical recommendations for avoiding Z-effect and reverse Z-effect type complications. Patient Saf Surg 5:17
86. Konstantinidis L, Papaioannou C, Blanke P, Hirschmuller A, Sudkamp NP, Helwig P (2013) Failure after osteosynthesis of trochanteric fractures. Where is the limit of osteoporosis? Osteoporos Int 24:2701–2706
87. Raviraj A, Anand A, Chakravarthy M, Pai S (2012) Proximal femoral nail antirotation (PFNA) for treatment of osteoporotic proximal femoral fractures. Eur J Orthop Surg Traumatol 22:301–305
88. Erhart S, Schmoelz W, Blauth M, Lenich A (2011) Biomechanical effect of bone cement augmentation on rotational stability and pull-out strength of the Proximal Femur Nail Antirotation. Injury 42:1322–1327
89. Guo Q, Shen Y, Zong Z, Zhao Y, Liu H, Hua X, Chen H (2013) Percutaneous compression plate versus proximal femoral nail anti-rotation in treating elderly patients with intertrochanteric fractures: a prospective randomized study. J Orthop Sci 18:977–986
90. Huang Y, Zhang C, Luo Y (2013) A comparative biomechanical study of proximal femoral nail (InterTAN) and proximal femoral nail antirotation for intertrochanteric fractures. Int Orthop 37:2465–2473
91. Knobe M, Nagel P, Maier KJ, Gradl G, Buecking B, Sonmez TT, Modabber A, Prescher A, Pape HC (2016) Rotationally stable screw-anchor with locked trochanteric stabilizing plate versus proximal femoral nail antirotation in the treatment of AO/OTA 31A2.2 fracture: a biomechanical evaluation. J Orthop Trauma 30:e12–e18
92. Liu Y, Tao R, Liu F, Wang Y, Zhou Z, Cao Y, Wang H (2010) Mid-term outcomes after intramedullary fixation of peritrochanteric femoral fractures using the new proximal femoral nail antirotation (PFNA). Injury 41:810–817
93. Macheras GA, Koutsostathis SD, Galanakos S, Kateros K, Papadakis SA (2012) Does PFNA II avoid lateral cortex impingement for unstable peritrochanteric fractures? Clin Orthop Relat Res 470:3067–3076
94. Stern R, Lubbeke A, Suva D, Miozzari H, Hoffmeyer P (2011) Prospective randomised study comparing screw versus helical blade in the treatment of low-energy trochanteric fractures. Int Orthop 35:1855–1861
95. Sawaguchi T, Sakagoshi D, Shims Y, Ito T, Goldhahn S (2014) Do Design adaptations of a trochanteric nail make sense for Asian patients? Results of a multicenter study of the PFNA-II in Japan. Injury 45:16241631
96. Takigami I, Matsumoto K, Ohara A, Yamanaka K, Naganawa T, Ohashi M, Date K, Shimizu K (2008) Treatment of trochanteric fractures with the PFNA (proximal femoral nail antirotation) nail system—report of early results. Bull NYU Hosp Jt Dis 66:276–279
97. Tang P, Hu F, Shen J, Zhang L, Zhang L (2012) Proximal femoral nail antirotation versus hemiarthroplasty: a study for the treatment of intertrochanteric fractures. Injury 43:876–881
98. Tao R, Lu Y, Xu H, Zhou ZY, Wang YH, Liu F (2013) Internal fixation of intertrochanteric hip fractures: a clinical comparison of two implant designs. ScientificWorldJournal 2013:834825
99. Wild M, Jungbluth P, Thelen S, Laffree Q, Gehrmann S, Betsch M, Windolf J, Hakimi M (2010) The dynamics of proximal femoral nails: a clinical comparison between PFNA and Targon PF. Orthopedics 33
100. Xu Y, Geng D, Yang H, Wang X, Zhu G (2010) Treatment of unstable proximal femoral fractures: comparison of the proximal femoral nail antirotation and gamma nail 3. Orthopedics 33:473
101. Xu YZ, Geng DC, Mao HQ, Zhu XS, Yang HL (2010) A comparison of the proximal femoral nail antirotation device and dynamic hip screw in the treatment of unstable pertrochanteric fracture. J Int Med Res 38:12661275
102. Yaozeng X, Dechun G, Huilin Y, Guangming Z, Xianbin W (2010) Comparative study of trochanteric fracture treated with the proximal femoral nail anti-rotation and the third generation of gamma nail. Injury 41:12341238
103. Zeng C, Wang YR, Wei J, Gao SG, Zhang FJ, Sun ZQ, Lei GH (2012) Treatment of trochanteric fractures with proximal femoral nail antirotation or dynamic hip screw systems: a meta-analysis. J Int Med Res 40:839–851
104. Knobe M, Gradl G, Buecking B, Gackstatter S, Sonmez TT, Ghassemi A, Stromps JP, Prescher A, Pape HC (2015) Locked minimally invasive plating versus fourth generation nailing in the treatment of AO/OTA 31A2.2 fractures: a biomechanical comparison of PCCP((R)) and Intertan nail((R)). Injury 46:1475–1482
105. Kim SY, Kim YG, Hwang JK (2005) Cementless calcar-replacement hemiarthroplasty compared with intramedullary fixation of unstable intertrochanteric fractures. A prospective, randomized study. J Bone Joint Surg Am 87:2186–2192
106. Kim Y, Moon J, Hwang K, Choi I, Kim Y (2014) Cementless bipolar hemiarthroplasty for unstable intertrochanteric fractures in octogenarians. Acta Orthop Traumatol Turc 48:424–430
107. Stappaerts KH, Deldycke J, Broos PL, Staes FF, Rommens PM, Claes P (1995) Treatment of unstable peritrochanteric fractures in elderly patients with a compression hip screw or with the Vandeputte (VDP) endoprosthesis: a prospective randomized study. J Orthop Trauma 9:292297
108. Emami M, Manafi A, Hashemi B, Nemati A, Safari S (2013) Comparison of intertrochanteric fracture fixation with dynamic hip screw and bipolar hemiarthroplasty techniques. Arch Bone Joint Surg 1:14–17
109. Broos P, Willemsen P, Rommens P, Stappaerts K, Gruwez J (1989) Pertrochanteric fractures in elderly patients. Treatment with a longstem/long-neck endoprosthesis. Unfallchirurg 62:234–239
110. Broos P, Rommens P, Deleyn P, Geens V, Stappaerts K (1991) Pertrochanteric fractures in the elderly: are there indications for primary prosthetic replacement? J Orthop Trauma 5:446–451
111. Bonnevialle P, Saragaglia D, Ehlinger M, Tonetti J, Maisse N, Adam P, Le Gall C (2011) Trochanteric locking nail versus arthroplasty in unstable intertrochanteric fracture in patients aged over 75 years. Orthop Traumatol Surg Res 97:S95–S100
112. Claes H, Broos P, Stappaerts K (1985) Pertrochanteric fractures in elderly patients: treatment with Ender's nails, blade-plate or endoprosthesis? Injury 16:261–264
113. Sinno K, Sakr M, Girar J, Khatib H (2010) The effectiveness of primary bipolar arthroplasty in treatment of unstable intertrochanteric fractures in elderly patients. North Am J Med Sci 2:561–568
114. Kayali C, Agus H, Ozluk S (2006) Treatment for unstable intertrochanteric fractures in elderly patients: internal fixation versus cone hemiarthroplasty. J Orthop Surg 14:240–244
115. Patil A, Ansari M, Pathak A, Goregaonkar AB, Thakker CJ (2013) Role of Cemented Bipolar Hemiarthroplasty for Comminuted Inter-trochanteric Femur Fracture in elderly osteoporotic patients through a modified Transtrochanteric approach-"SION Hospital Modification". IOSR J Dental Med Sci 9:40–47
116. Cho S, Cho H, Cho H (2014) Primary cementless hip arthroplasty in unstable intertrochanteric femur fracture in elderlys: short-term results. Hip Pelvis 26:157–165