The Safety and Efficacy of Internal Fixation for Ipsilateral Femoral Neck and Shaft Fractures: A Systematic Review and Meta-analysis

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Abstract

Objectives
To the best of our knowledge, no systematic reviews have been carried out to assess the efficiency of reduction of combined neck-shaft injuries. Therefore, this systematic review aimed to summarize the current evidence regarding the application of internal fixation in the management of ipsilateral fractures of the femoral neck and shaft (IFIFNSF).
Materials and methods
A comprehensive bibliographic search was performed from 2000 to December 2020 at four electronic databases. We included studies that included patients with IFFNS.
Results
We identified seven studies that evaluated IFIFNSF with a total of 257 cases. Recon Nail had slightly better range of motion (ROM) parameters than Long Gamma Nail. The hospital stay was similar between cancellous lag screws or DHS+ compression plate fixation and PFNA-long. We did not find superiority between the all-in-one device, conventional and surgical techniques regarding daily impairment activities, Pain, and Loss of hip or knee ROM. Three studies reported complications incidence, with a notable more frequent higher incidence in the LC-DCP + cancellous screws (67%). It was lowest in PFNA-long (0%) and cancellous lag screws or DHS+ compression plate fixation (9%).
Conclusion
In conclusion, the optimum sequence or fixation procedure for stabilizing IFFNS has not been identified yet; surgeons should select an operational strategy that maximizes anatomic reduction and sufficient neck fracture stabilization and restores the normal length and rotation.

Keywords
Femoral Fractures; Internal Fixation; Shaft Fracture; Neck Fractures.

Introduction

High-energy injuries, including ipsilateral fractures of the femoral neck and shaft (IFFNS), are difficult to treat [1]. According to previous studies, IFFNS occur in 2.5% to 6% of all femoral shaft fractures [2]. Due to several factors, treating a combined femoral neck-shaft fracture is more complex and complicated than treating each fracture separately [3]. Although there is little evidence on the best way to treat these fractures, the fixation time, the fracture fixation sequence, and implant selection must be considered [4]. However, the target of care for this injury pattern is the excellent reduction of both fractures.

For these high-energy injuries, there is an agreement that early and effective fixation is sufficient and required to reduce morbidity and mortality and helps patients to be mobilized and rehabilitated as early as possible [5]. Either fracture reduction or fixation should be provided in the context of the overall condition of the patient. In surgical preparation, the difficulty and effectiveness of late reconstructive procedures should be considered [6]. Such fractures are usually observed in young individuals with polytrauma, and possible associations, including nonunion fractures and osteonecrosis [7,8].

To date, there is no strong evidence that favors any internal fixation technique. The accuracy of fracture fixation has been stated to have a significant impact on both neck and shaft fractures, including long-term outcomes [9]. To the best of our knowledge, no systematic reviews have been carried out to assess the efficiency of reducing combined neck-shaft injuries. Therefore, we aimed to systematically identify all literature regarding the application of internal fixation in the management of IFFNS.

Materials and methods

Literature search

A comprehensive bibliographic search was performed from 2000 to December 20202 at four electronic databases: PubMed, Scopus, Web of Science, and Cochrane Library. We performed a search for all published articles that evaluated the internal fixation of the IFFNS. We searched article title, abstract, keywords using the following keywords: *"Internal fixation", " neck", "shaft ", "femur", "femoral", "fracture"*. We used "OR" and "AND" operators during the Literature search as following: *"Internal fixation" AND (neck AND shaft) AND (femur OR femoral) AND fracture*. We searched for articles that were included in previous related systematic reviews. The identified citations were retrieved using the Endnote X8 software package (Thompson Reuter, USA).

Eligibility criteria

We included studies that met our following inclusion criteria: studies included patients with IFFNS, studies comparing methods for internal fixation, and studies that reported safety and efficacy outcomes. We excluded animal studies, reviews, book chapters, thesis, editorial letters, and papers with the overlapped dataset. The retrieved records were then exported to EndNote X8, and the duplicates were removed before the screening phase. Two independent reviewers screened the retrieved records in two stages; in the first stage, the titles and the abstracts of all records were screened for eligibility. Only records deemed eligible during the first stage were downloaded, and their full texts were screened for final decision. The discrepancies between reviewers were resolved by consensus at any stage of the screening process

Data extraction

Four independent reviewers extracted the data from eligible studies using a standardized Excel sheet for data retrieval and processing. The following data were extracted from each eligible study: first author, study design, sample size, injury description, interventions, patients' baseline characteristics, and disease severity. Additionally, we extracted functional, radiological outcomes and incidence of complications.

Results

Result of literature search

Initially, a total of 165 unique records were retrieved and screened for eligibility. Out of them, 44 potentially eligible full texts were downloaded and thoroughly screened for eligibility. Seven studies were deemed eligible and included in the present systematic review (Figure1) [10-16].

Characteristics of included studies

We identified seven studies that evaluated the internal fixation of IFFNS with a total of 257 cases. The mean age of patients across the studies ranged between 19 and 50 years except for Tsai 2009 and Ruden 2015; authors included patients above 60 years. There was male predominance in the included cases. Three studies were prospective design, two studies were retrospective, and one study was biomechanical analysis. A summary of the reported techniques is shown in Table 1.

Three studies reported operative details; cancellous lag screws or DHS+ compression plate fixation had the highest blood loss (600 mL) with extended duration of surgery 255 min compared to other techniques (11,12,14). The duration of surgery was comparable between LC-DCP + DHS, LC-DCP + cancellous screws, antegrade IM nail + cancellous screws, and cancellous lag screws or DHS+ compression plate fixation. Long Gamma Nail had the lowest blood loss (282 mL) and duration of surgery (88 min). Table 2

Functional outcomes

A variety of outcomes were reported across the studies. Three studies reported Friedman and Wyman classification [11,14,16]. All techniques had a good function, with a low number of cases had a poor function. Table3, Figure 2

Harris Hip Score was reported by two studies [10,12]. The mean score was 86 in Recon nail, 84 in Long Gamma nail, 99 in Gamma nail, and 94 in Sirus nail. Table4, Figure 3

Recon Nail had slightly better range of motion (ROM) parameters than Long Gamma Nail. The hospital stay was similar between cancellous lag screws or DHS+ compression plate fixation and PFNA-long. We did not find superiority between the all-in-one device, conventional and surgical techniques regarding daily impairment activities, pain, and hip or knee ROM loss. Table5

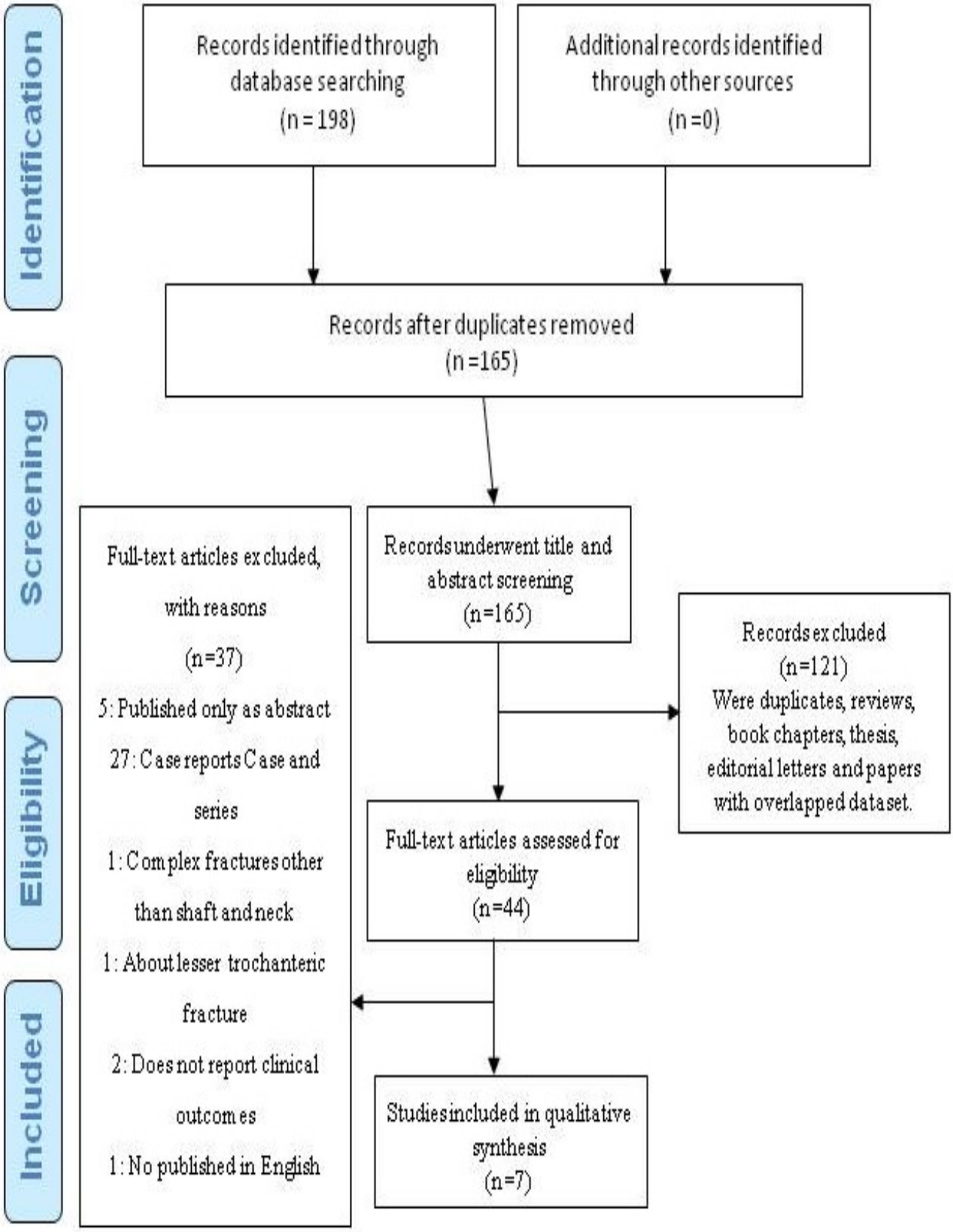

Figure 1: PRISMA flow diagram showing process of studies selection

Table 1: Characteristics of included studies.

Author Year	Design	N	Injury description	interventions (n)	Age years Mean(range)	Male \ Female	Injury Severity Score	Open fracture N,(class)	follow-up (months)
Starr 2006	Prospective, randomized	34	subtrochanteric, intertrochanteric, or ipsilateral femoral neck/shaft fracture due to a high-energy injury	Russell-Taylor Recon Nail (17)	32 (19–45)	……	15(9–29)*	1 (II)	15
				Howmedica Long Gamma Nail (17)	37 (19–50)		15(9–48)*	2 (II, IIIA)	16
Tornetta 2007	Prospective,	23	To evaluate a protocol that lower the risk of missing femoral neck fracture in all patients with a femoral shaft fracture *		……	……	…….	……..	……..
Tsai 2009	retrospective	43	ipsilateral femoral shaft and neck fractures	LC-DCP + DHS (8)	43 (17–73)	28 \ 15	…….	…….	48
				LC-DCP + cancellous screws (9)					
				Antegrated IM nail + cancellous screws (21)					
				Reconstruction nail (5)					
Vidyadhara 2009	prospective	43	ipsilateral femoral shaft and neck fractures	Gamma nail (20)	41.5 (31–55)	13 \ 7	…….	5 (I) ,11 (II)	……..
				Sirus nail (23)	44.3 (29–48)	19\ 4		8 (I) ,7 (II)	
Wu 2009	Biomechanical analysis	28	ipsilateral femoral shaft and neck fractures	Supplementary cannulated screw	……..	……..	…….	……..	……..
Wang 2010	retrospective	21	Ipsilateral basicervical femoral neck and shaft fractures	cancellous lag screws or DHS+ compression plate fixation (11)	41 (25–55)	9 \ 2	…….	……..	22.2
				PFNA-long (10)	43 (27–60)	9 \ 1			20.8
Ruden 2015	……..	65	proximal and shaft of the femur fractures	All-in-one device (36)	45 (19–90).	…….	…….	……..	24
				Conventional (16)					
				surgical (9) ^					

* ***Protocol****: Anteroposterior internal rotation plain radio-graph, a fine (2-mm) cut computed tomographic scan through the femoral neck, and an intraoperative fluoroscopic lateral radiograph before fixation as well as postoperative anteroposterior and lateral radiographs of the hip in the operating room before awakening the patient*

*- ^**Surgical** technique, e.g., the combination of retrograde intramedullary nailing and DHS osteosynthesis, **All-in-one device** technique, e.g., long cephalomedullary nail, compared with two non-overlapping implants (e.g., **conventional** technique), **DHS**: dynamic hip screw, **LC-DCP**: low-contact dynamic compression plate, **PFNA-long**: long proximal femoral nail anti-rotation*

Table2: Operative details of the reported techniques.

Study ID	Reported techniques	Estimated blood loss (mL)	Duration of surgery	Postoperative drainage (ml)
Starr 2006	Recon Nail	328 (100–750)	106 (55–125)	….
	Long Gamma Nail	282 (100–700)	88 (57–140)	….
Tsai 2009	LC-DCP + DHS	525	277.5	….
	LC-DCP + cancellous screws	427	277.7	….
	Antegraded IM nail + cancellous screws	422	278.3	….
	Reconstruction nail	300	301	….
Wang 2010	cancellous lag screws or DHS+ compression plate fixation	600 (400–1200)	255 (215–350)	358 (150–550)
	PFNA-long	480 (200–1000)	217 (155–335)	278 (100–500)

Table3: Summary of Friedman and Wyman classification for the reported techniques.

Study ID	Reported techniques	Good n(%)	Fair n(%)	Poor n(%)
Tsai 2009	LC-DCP + DHS (n =8)	7 (88%)	1 (13%)	0 (0%)
	LC-DCP + cancellous screws (n =9)	7 (78%)	2 (22%)	0 (0%)
	Antegraded IM nail + cancellous screws (n =21)	15 (71%)	4 (19%)	2 (10%)
	Reconstruction nail (n =5)	4 (80%)	1 (20%)	0 (0%)
Wang 2010	cancellous lag screws or DHS+ compression plate fixation (n =11)	8 (73%)	2 (18%)	1 (9%)
	PFNA-long (n =10)	8 (80%)	1 (10%)	1 (10%)
Ruden 2015	All-in-one device (n = 36)	28 (78%)	6 (17%)	2 (6%)
	Conventional (n = 16)	12 (75%)	2 (13%)	2 (13%)
	surgical (n = 9)	٧ (78%)	2 (22%)	0 (0%)

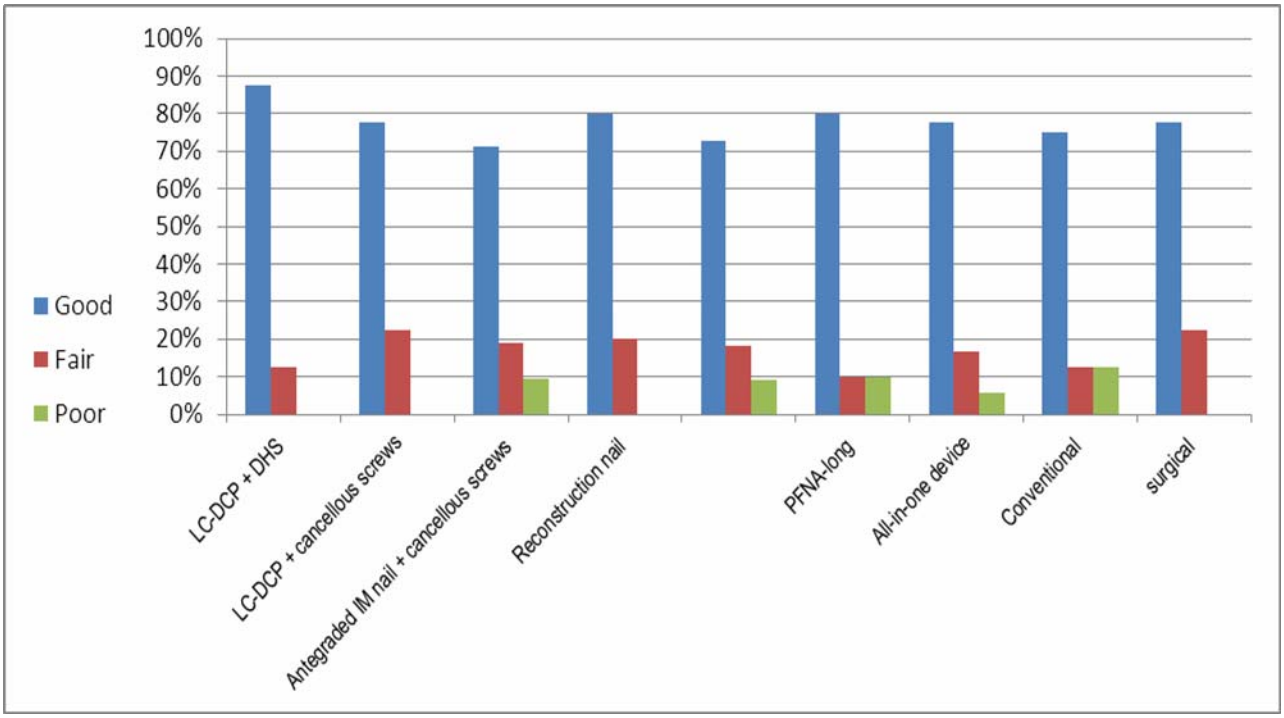

Figure 2: Friedman and Wyman classification.

Table4: Harris Hip Score at last follow-up for the reported techniques.

Study ID	Reported techniques	Harris Hip Score
Starr 2006	Recon Nail	86 (71–100)
	Long Gamma Nail	84 (50–100)
Vidyadhara 2009	Gamma nail	92 4 (86–98)
	Sirus nail	94 3 (93–100)

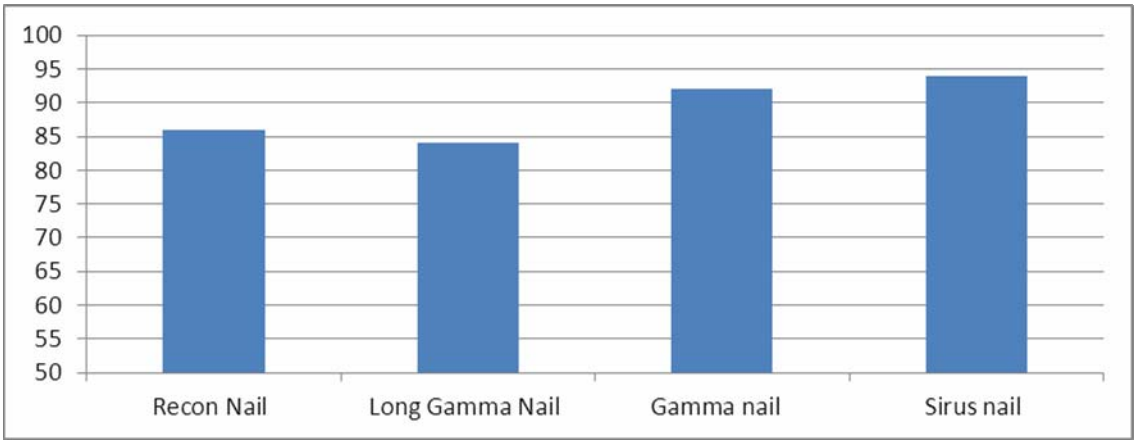

Figure 3: Harris Hip Score.

Table5: Summary for the remaining functional outcomes.

Study ID	Outcomes		Recon Nail (n = 15)	Long Gamma Nail (n = 13)	
Starr 2006	Ambulate independently		15	12	
	Returned to work		12	12	
	Hip range of motion	Flexion	1111	1101	
		Extension	121	91	
		Abduction	321	301	
		Adduction	191	151	
		Internal rotation	171	171	
		External rotation	301	251	
	Knee range of motion*		1141	1141	
Study ID	Outcomes		Gamma nail (n = 17)	Sirus nail (n = 20)	
Vidyadhara 2009	Sliding of the lag screw (mm)		5.2 2 (0–8)	2.3 1.2 (1–4.6)	
	Shortening <10 mm		4	2	
	Difficult squatting and sitting cross-legged (n)		1	0	
Study ID	Outcomes		cancellous lag screws or DHS+ compression plate fixation (n = 11)	PFNA-long (n =10)	
Wang 2010	Hospital stay (days)		28.7 (11–65)	27.7 (12–62)	
Study ID	Outcomes		All-in-one device (n = 36)	Conventional (n = 16)	surgical (n = 9)
Ruden 2015	Impairment daily activities	None	30	11	8
		Mild	5	5	1
		Moderate	1	0	0
	Pain	None	24	12	7
		Mild/moderate	10	4	2
		Severe	2	1	0
	Loss of hip or knee ROM (%)	<20	28	13	8
		20–50	7	2	1
		>50	1	1	0
Tornetta 2007	Delayed Diagnosis of associated Femoral Neck Fracture		the protocol reduced the delay in diagnosis of by 91%		

Complications

Three studies reported complications incidence [11,14,16]. It was highest in LC-DCP + cancellous screws (67%) and antegrade IM nail + cancellous screws (67%).It was lowest in PFNA-long (0%) and cancellous lag screws or DHS+ compression plate fixation (9%).Table6, Figure 4

Table6: Incidence of complications.

Study ID	Reported techniques	Incidence of complications n(%)
Tsai 2009	LC-DCP + DHS (n =8)	2 (25%)
	LC-DCP + cancellous screws (n =9)	6 (67%)
	Antegraded IM nail + cancellous screws (n =21)	14 (67%)
	Reconstruction nail (n =5)	1 (20%)
Ruden 2015	All-in-one device (n = 36)	13 (36%)
	Conventional (n = 16)	5 (31%)
	surgical (n = 9)	3 (33%)
Wang 2010	cancellous lag screws or DHS+ compression plate fixation (n =11)	1 (9%)
	PFNA-long (n = 10)	0 (0%)

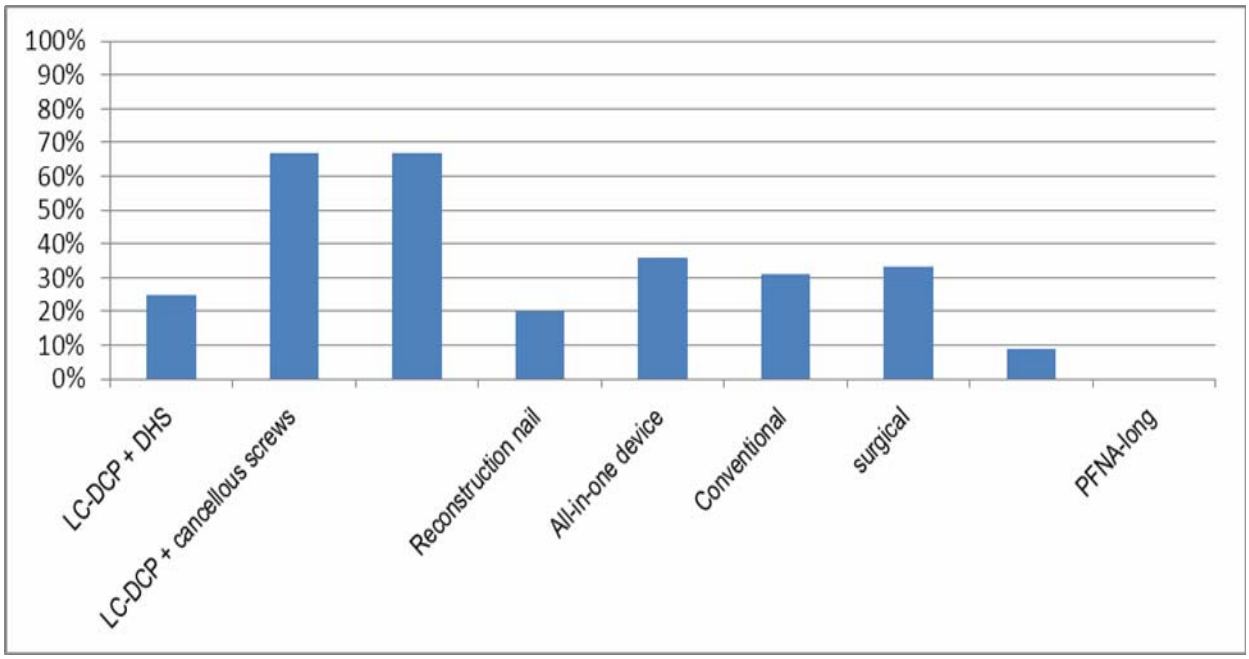

Figure 4: complications rate.

Radiological outcomes

Two studies reported radiological outcomes [10,11]. Sirus nail had higher neck fracture reduction and less tip–apex distance compared to Gamma nail. The rate of fracture healing was similar between the all-in-one device, conventional and surgical techniques. Table7

Table7: Reported radiological outcomes.

Study ID	Outcomes		Gamma nail (n = 20)	Sirus nail (n = 23)	
Vidyadhara 2009	Neck fracture reduction	Good	3	14	
		Acceptable	15	9	
		Poor	2	0	
	Tip–apex distance	<10 mm	14	22	
		10–20 mm	3	1	
		>20 mm	3	0	
Study ID	Outcomes		All-in-one device (n = 36)	Conventional (n = 16)	surgical (n = 9)
Ruden 2015	Fracture healing		33	15	9

Discussion

Internal fixation for IFFNS has always been a source of debate. Therefore, we have reviewed the current evidence on various fixation methods in this study due to the restricted possibilities for inserting interlocking screws. The intermediate fragment, in particular, is not adequately stabilized [17]. Revision surgery has also been found to be difficult due to the removal of hardware and the presence of residual bone stock [18]. Nevertheless, there was no obvious indication that utilizing a single or two separate devices for the fixation of these combination fractures was superior.

According to Rüden et al., using an all-in-one system produced comparable results to other surgical approaches regarding the number of healed fractures, the rate of complications, and several functional outcomes such as pain and range of motion [16]. Tsai et al. demonstrated that there were no significant differences in blood loss, surgical time, complications, or clinical outcomes between reconstruction nails and other techniques [11]. According to an old systematic review with weak evidence, separate femoral neck and shaft implants result in fewer reoperations than a single-implant procedure [19]. There is also a debate about using one or two femoral neck screws to support femoral neck fractures during the nailing reconstruction. However, we found that using two screws resulted in marginally better results, regardless of the weak evidence. Vidyathara and Rao showed minor improvements in the functional outcomes following two femoral neck screws. Furthermore, patients who were managed with nails and one screw had screw cut-out. [10]. Patients who were treated with long gamma nails (one screw) had a higher rate of varus malalignment than those who were treated with recon nails (two screws), according to Starr et al. We should take into consideration that this malalignment maybe relates to the larger diameter of the long gamma nail (17mm) compared to recon nail (14mm or 12mm) [12].

In comparison to transcervical fractures, Wu and Tai reported superior outcomes with cannulated screws [15]. In patients with a high risk of osteoporotic cut-out, it appears that two lag-screw configurations should be avoided. As a result, single screw designs can be recommended in elderly patients with poor bone quality. Two screw configurations (with the upper screw slightly larger than the lower) could be safer. While in cases of non-displaced femoral neck fractures, it is possible to start with the shaft by retrograde nail insertion followed by neck fixation [20].

Although the perfect fixing sequence is still unknown, previous studies have proposed fixing the neck initially to avoid a displacement of a minimum displacement fracture. Moreover, it may help in increasing neck stability and prevent osteonecrosis [21]. On the other hand, some investigators suggested that fixing the shaft fracture first would help in reducing the neck and prevent destabilizing neck fracture fixation when fixing the shaft fracture [22]. Starr et al. observed that there was no significant difference between the two entry points, Russell-Taylor Recon Nail and Long Gamma Nail, in terms of blood loss, incision length, operating room time, ease of use, or complications rate [12].

Plates are another choice for shaft fixing, and they can be used before or after femoral neck stabilization because they are less likely to trigger femoral neck displacement compared to retrograde nailing [23]. However, fixation with plate had a higher incidence of infection and nonunion than nail fixation, there is a need to maintain weight-bearing restrictions, and it is best suited for an open fracture with large exposure. Plates have the advantage of having a low incidence of malalignment and a low chance of iatrogenic fracture displacement. [24]. According to Wang et al., the plate group had a longer operating time and more perioperative blood loss than the PFNA-long group, but there was no substantial difference in functional outcomes or major complications [14]. In Tsai et al., LC-DCP combined with DHS resulted yielded good functional outcomes along with low complication nails similar to reconstruction nails [11].

A missed neck femur fracture is an important concern that was raised in the literature [21]. Vidyathara and Rao reported no delay in diagnosing femoral neck fracture (10). Tornetta et al. developed a protocol to enhance fracture detection, which reduced the delay by more than 90% [25]. The rare nature of this injury makes it very challenging to study, and most published studies had very small sample sizes.

Conclusion

The optimum sequence or fixation procedure for stabilizing IFFNS has not been identified yet; surgeons should select an operational strategy that maximizes anatomic reduction and sufficient neck fracture stabilization and restores the length and rotation of the femoral shaft.

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