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Outcomes of internal fixation with Femoral Neck System (FNS) for intracapsular femoral neck fractures

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Abstract

Background: Internal fixation of hip fractures is associated with high reoperation rates. This study investigated the reoperation rates after internal fixation with the femoral neck system (FNS).

Materials and Methods: A single-institution cohort study was conducted on patients aged 18 years or older who sustained intracapsular femoral neck fractures and underwent internal fixation with a fixed-angle implant. Surgeons, patients, and investigators were not blinded. The primary outcome was any hip reoperation at the final follow-up. Secondary outcomes were to characterize a cohort of patients regarding demographics, fracture classification, intraoperative findings, postoperative fracture complications and union rates, and postoperative pain.

Results: This study found that internal fixation with FNS for intracapsular femoral neck fractures was associated with a 23% rate of revision surgery. Of the initial 94 patients who received FNS internal fixation, 44 patients were included for analysis; of those, 10 patients underwent revision surgery. Patients had a 22% rate of in-hospital medical adverse events with a 30-day readmission rate of 9%. Increasing body mass index was associated with increased revision rates ($P = 0.037$). Patients who sustained displaced femoral neck fractures had a significant decrease in SF-12 Mental Health Composite, SF-12 Physical Health Composite, and quality-of-life subscale scores.

Conclusions: The FNS is a viable alternative for internal fixation of intracapsular femoral neck fractures. The observed rate of revision after internal fixation was comparable with previously published outcomes following fixation with cannulated screws and sliding hip screws.

Level of Evidence: Level IV, Therapeutic Study.

1. Introduction

Hip fractures are associated with poor outcomes, mortality up to 30% at 1 year, and a substantial impact to the health care system in the United States.[1] Even among patients assigned to standard care groups in which the time from diagnosis to surgery is less than 24 hours, there is a 10% mortality risk and 22% rate of major complications at 90 days after fracture.[2] Major complications include mortality, nonfatal myocardial infarction (MI), stroke from venous thromboembolism (VTE), sepsis, pneumonia, and life-threatening or major bleeding.[2]

The American Academy of Orthopedic Surgeons clinical guidelines for hip fractures in elderly patients state that (1) surgery within 24–48 hours of admission may be associated with better outcomes, (2) internal fixation for patients with stable (nondisplaced) fractures may be considered, and (3) arthroplasty is preferred for patients with unstable (displaced) fractures.[3] In an international survey, most surgeons preferred internal fixation in displaced fractures in patients younger than 60 years and arthroplasty (hemiarthroplasty vs. total hip arthroplasty) in patients older than 80 years and their choice of implant preference varied in patients aged 60–80 years with displaced fractures.[4]

The Femoral Neck System (FNS, DePuy Synthes; Monument, CO) shares the minimally invasive advantage of cannulated screws

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(CSs) with a smaller side-plate footprint than other fixed-angle devices and requires less soft-tissue disruption. Unlike CS, the FNS possesses fixed-angle stability. Biomechanical studies have shown no significant difference in mean axial stiffness and cycles until 15-mm leg shortening between the FNS and a sliding hip screw (SHS) in femoral neck cadaver models.[5] The implant design is a side-plate, bolt, and antirotation screw that provides angular and rotational stability. The collapsing bolt allows compression through the fracture site. FNS internal fixation may be a viable alternative for fixation of intracapsular femoral neck fractures. We conducted this study to determine the rates of reoperation of internal fixation with the FNS and to characterize our cohort of patients. We hypothesized that FNS would have comparable revision rates with conventional standards reported in literature.

2. Materials and Methods

2.1. Study Design

This study was approved by a local institutional review board. A single-institution cohort study was conducted to analyze patients who sustained intracapsular femoral neck fractures and underwent internal fixation with a fixed-angle implant. Eligible patients underwent fixation over a 4-year period from June 2019 to May 2023, and data were recorded at their final available follow-up appointment. Patients were included in the final analysis if they achieved >3-month clinical follow-up and postoperative radiographs. The study was conducted from June 2019 to May 2023. For article preparation, the STROBE checklist was used.[6]

2.2. Eligibility

Inclusion criteria were as follows: (1) age 18 years or older, (2) femoral neck fracture confirmed with imaging, (3) surgical fixation with FNS, and (4) medical optimization and clearance before fixation.

Exclusion criteria were as follows: (1) femoral neck fractures treated nonoperatively, (2) concomitant ipsilateral or contralateral major lower extremity injury, (3) previous hip surgery or retained hardware, peri-implant hip fracture, and (4) pathologic fracture.

2.3. Interventions

Patients underwent operative fixation of intracapsular femoral neck fractures with the FNS. The participating surgeons were fellowship-trained experienced orthopaedic trauma surgeons who practice at level 1 trauma centers and see a high volume of operative hip fractures. Surgeons chose patient positioning, surgical exposure, reduction techniques, implant positioning, and postoperative weight-bearing status. Participating surgeons followed current hip fracture guidelines including surgery within 24 hours of fracture (unless medical delay is indicated), perioperative antibiotics, postoperative thromboprophylaxis, perioperative management by an internal medicine team, physical and occupational therapy evaluation and treatment, and early mobility protocols. Patients were not excluded for deviations from these clinical practice guidelines. Surgeons, patients, and investigators were not blinded.

2.4. Patient Demographics and Injury Characteristics

Demographic data obtained included the following: age, race, body mass index (BMI), tobacco use, medication class, American Society of Anesthesiologists (ASA) physical classification score, preinjury ambulation status, and preinjury residence. Injury characteristics included mechanism of injury, additional injuries, and hip fracture laterality. Fracture characteristics included fracture level, Garden classification, and Pauwels angle.

2.5. Outcome Measures

The primary outcome was the rate of reoperation among patients undergoing internal fixation with the FNS at the final radiographic follow-up. This was defined as any reoperation to promote fracture healing, relieve pain, treat infection, treat a periprosthetic fracture, or improve function. Intraoperative findings included tip-to-apex distance, intraoperative blood loss, and surgical duration. Postoperative patient characteristics were collected including medical complications, 30-day readmission rates, and weight-bearing status. Fracture complications were collected such as implant failure, implant cutout, avascular necrosis, painful hardware, intractable pain due to wear of the acetabulum, periprosthetic femur fracture, and nonunion. For patients who required a reoperation, implant removal or exchange was recorded. Postoperative health-related quality-of-life scores were collected using the visual analog pain scale (VAS), Western Ontario and McMaster University Osteoarthritis Index (WOMAC), Hip Disability and Osteoarthritis Outcome Score (HOOS), SF-12 Mental Health Composite score (MCS), and SF-12 Physical Health Composite score (PCS).

2.6. Statistical Analyses

Study data were collected and managed using REDCap (Research Electronic Data Capture)[7,8] and downloaded into IBM SPSS Statistics, version 29.0, for analyses. Continuous data were evaluated for normality; when this assumption was held, these were summarized as means and standard deviations (SDs); otherwise, these were reported as medians and interquartile ranges (IQRs) or minimum and maximum values. Categorical data were summarized as frequencies and percentages. Two-sided tests were conducted for group comparisons. For continuous variables, either the independent-samples *t* test (with the Levene test for equal variance assumptions) or the Mann–Whitney U exact test (for skewed and sparse data) was conducted. For group comparisons of categorical data, the Fisher exact test was conducted. No adjustments were made for conducting multiple tests.

3. Results

A total of 94 patients were assessed for eligibility over a 4-year period from June 2019 to May or June 2023. As in other investigations,[9,10] patients were included in the final analysis if they achieved at least 3-month follow-up after surgery with available clinical and radiographic follow-up. 34 patients were excluded from the final analysis: no postoperative clinical follow-up (n = 22), lower extremity injuries (n = 6), declined to participate (n = 3), surgery completed at another facility (n = 2), and severe dementia (n = 1). Of the 60 patients who were included in the study, 16 were lost to follow-up.

As given in Table 1, 44 patients were included in the analysis whose mean age at time of surgery was 70.0 years (SD 15.0). Most were female, 61.4% (27 of 44), and over 90% were Caucasian, were a healthy weight (BMI 18.5–24.9, 54.5%), never used tobacco (45.5%), reported using antihypertensive

TABLE 1

Patient Characteristics

Characteristics	n = 44	%
Patient characteristics at baseline		
Mean age at time of surgery (SD)	70.0 (15.0)	
Female	27	61.4
Male	17	38.6
Race		
Caucasian	40	90.9
Black or African American	2	4.5
American Indian	1	2.3
Unknown	1	2.3
BMI		
Underweight (<18.5)	2	4.5
Healthy weight (18.51–25)	24	54.5
Overweight (25.1–30)	9	20.5
Obese (>30)	9	20.5
Tobacco use		
Never use	20	45.5
Former use	9	20.5
Current use	14	31.8
Unknown	1	2.3
Current medication use		
Antihypertensive	22	50.0
Cardiac	17	38.6
Pulmonary	13	29.5
Diabetic	12	27.3
Osteoporotic	10	22.7
Opioid analgesics	8	18.2
Other medication	24	54.5
ASA score		
I normal healthy	3	6.8
II mild systemic disease	12	27.3
III severe systemic disease	26	59.1
IV severe systemic disease with constant threat to life	3	6.8
Preinjury ambulation status		
Without assistive device	27	64.3
Walker	9	21.4
Cane	3	7.1
Wheelchair	3	7.1
Preinjury residence		
Independent	37	84.1
Nursing home	3	6.8
Assisted living	2	4.5
Other institutions	2	4.5
Details of injury		
Mechanism of injury		
Fall	37	84.1
Motor vehicle crash	3	6.8
Bicycle crash	2	4.5
Spontaneous	1	2.3
Other low-energy trauma	1	2.3
Additional injuries	4	9.1
Fractured hip		
Left	22	50.0
Right	22	50.0

medications (50.0%), had an ASA score of III severe systemic disease (59.1%), were ambulatory without an assistive device (64.3%), and said a fall was the mechanism of injury (84.1%).

Table 2 summarizes the characteristics of the fractures and surgical outcomes. Most had a subcapital fracture level, 59.1% (26 of 44); Garden classification II, nondisplaced, 50.0% (22 of 44); and Pauwels angle type 2: 30–50 degrees from horizontal, 52.3% (23 of 44). 97.7% (43 of 44) had an acceptable intraoperative reduction. 22.7% (10 of 44) required a reoperation at the final follow-up, although 84% (37 of 44) achieved a fracture union. 6.8% (3 of 44) went on to malunion (>10 mm of shortening in any plane). The primary reasons for reoperation were avascular necrosis (9.1%, 4 of 44), nonunion (9.1%, 4 of 44), intra-articular screw penetration (2.3%, 1 of 44), and periprosthetic fracture (2.3%, 1 of 44). The mean radiographic follow-up was approximately 12.6 months (SD 8.0). Patients who underwent revision surgery were revised approximately 10.1 months (SD 7.5) from their index procedure.

Patients were compared depending on whether revision surgery was required (Table 3). There were 10 patients (22.7%) who had a subsequent revision. However, patient characteristics did not seem to differ significantly, apart from BMI; those requiring revisions seemed to be heavier compared with those who did not (30.4 (7.5) versus 24.5 (4.3), respectively ($P = 0.037$)). As expected, patients with fracture union complications were more likely to undergo revision surgery ($P < 0.001$). 7 of 10 revisions were due to implant exchange with revision to total hip arthroplasty, 2 due to hemiarthroplasty, and 1 due to internal fixation with an intramedullary nail (Table 3).

Finally, this study compared nondisplaced (Garden I/II) fractures with displaced (Garden III/IV) fracture types (Table 4).

TABLE 2

Fracture Assessment and Surgical Outcomes

Description	n	%
Fracture assessments	44	
Fracture level		
Subcapital	26	59.1
Transcervical	15	34.1
Basicervical	3	6.8
Garden classification		
Nondisplaced		
Garden I	12	27.3
Garden II	22	50.0
Displaced		
Garden III	6	13.6
Garden IV	4	9.1
Pauwels angle (degrees from horizontal)		
Type 1: <30	5	11.4
Type 2: 30–50	23	52.3
Type 3: >50	16	36.4
Reduction		
Acceptable	43	97.7
Unacceptable	1	2.3
Surgical outcomes		
Patients who required a reoperation	10	22.7
Implant exchange: total hip arthroplasty	7	15.9
Implant exchange: hemiarthroplasty	2	4.5
Implant exchange: internal fixation	1	2.3
Fracture healing status		
Achieved union	37	84
Malunion	3	6.8
Nonunion	4	9.1
Primary cause of reoperation		
Avascular necrosis	4	9.1
Nonunion	4	9.1
Intra-articular screw penetration	1	2.3
Periprosthetic femur fracture	1	2.3
Follow-up details, n = 44		
Mean months (SD) from date of surgery to date of last XR		12.6 (8.0)
Mean months (SD) from date of surgery to revision procedure		10.1 (7.5)

TABLE 3

Comparison of Patients With and Without Revision Surgery

Description	n	Revision surgery	n	No revision	*P*
Patient characteristics, n (%)	10	10 (22.7)	34	34 (77.3)	
Pauwels angle					
Type 1 or 2		5 (50)		23 (67.6)	0.456
Type 3		5 (50)		11 (32.4)	
Fracture level					
Subcapital		5 (50)		21 (61.8)	0.626
Transcervical		4 (40)		11 (32.4)	
Basicervical		1 (10)		2 (5.9)	
Garden classification					
Displaced		4 (40)		6 (17.6)	0.199
Nondisplaced		6 (60)		28 (82.4)	
Reduction					
Acceptable		9 (90)		34 (100)	0.227
Unacceptable		1 (10)		0 (0)	
Mean (SD) age at time of surgery		64 (9.8)		71.7 (15.8)	0.153
Mean (SD) BMI*		30.4 (7.5)		24.5 (4.3)	**0.037**
Mean (SD) tip-to-apex distance; mm		23.0 (6.4)		25.8 (7.7)	0.298
Mean (SD) intraoperative blood loss		64.5 (36.1)		78.1 (54)	0.460
Median (IQR) surgical duration (minutes)‡		27.5 (23, 67)		36 (27, 46)	0.384
Mean (SD) length of hospital stay; days		4.5 (3.5)		4.4 (2.3)	0.900
Mean (SD) follow-up time: number of days from date of surgery to date of last XR	10	322.4 (208)	34	407.5 (251.5)	0.338
Surgical outcomes					
Discharged status	10		34		
Home		4(40)		17 (50.0)	0.329
Home with home health		0 (0)		4 (11.8)	
Skilled nursing		3 (30)		9 (26.5)	
Rehabilitation center		2 (20)		4 (11.8)	
Specialty hospital		1 (10)		0 (0)	
Did patient have any fracture complications?		8 (80)		4 (11.8)	**<0.001**
Patients with postoperative complication (patients may have experienced more than one)					
Implant cutout		3 (30)		0 (0)	0.009
Avascular necrosis		5 (50)		0 (0)	**<0.001**
Painful hardware		1 (10)		0 (0)	0.227
Intractable pain due to wear of the acetabulum		3 (30)		0 (0)	**0.009**
Periprosthetic femur fracture		1 (10)		0 (0)	0.227
Nonunion		4 (40)		0 (0)	**0.002**
Patients who required a reoperation					
Implant exchange: total hip arthroplasty		7 (70)		0 (0)	**<0.001**
Implant exchange: hemiarthroplasty		2 (20)		0 (0)	**0.048**
Implant exchange: internal fixation		1 (10)		0 (0)	0.227
30-d readmission†					
Yes		0 (0)		3 (8.8)	>0.999
No		10 (100)		31 (91.2)	

Bold indicates significance set at value of $P < 0.05$.
Results for mean comparisons are from the independent-samples *t* test with equal variances unless otherwise stated.
Mean (SD): mean and SD; median (IQR): median and interquartile range.
Results for frequencies and percentage comparisons are from the Fisher exact test.
* Equal variances not assumed.
† Adverse events (patients may have experienced more than one event): cardiovascular (1), pulmonary (1), decreased cognitive ability (1), neurological (1), renal (1), urinary (2), and others (3).

Significant differences were observed between groups for the Pauwels angle and fracture level. Those with a classification of nondisplaced fracture were more likely to have a type 1 or 2 Pauwels angle (82.4%, 28 of 34, $P < 0.001$) and a subcapital fracture level (76.5%, 26 of 34, $P < 0.001$). Patients who sustained displaced femoral neck fractures demonstrated no significant difference in revision surgery, 40% (4 of 10) for those with displaced fractures compared with 17.6% (6 of 34) for those with nondisplaced fractures ($P = 0.199$). Patients with displaced femoral neck fractures were less likely to achieve fracture union ($P = 0.008$) and more likely to develop nonunion ($P = 0.002$). Follow-up assessments indicated that those with nondisplaced fractures experienced significantly higher scores in the quality-of-life subscale ($P = 0.008$), SF-12 MCS ($P = 0.015$), and SF-12 PCS ($P = 0.021$).

4. Discussion

4.1. Key Results

This study found that internal fixation with FNS for intracapsular femoral neck fractures was associated with a 23% rate of revision surgery. Of the initial 94 patients who received FNS internal fixation, 44 patients were included for analysis and, of those, 10 patients underwent revision surgery. The mean radiographic follow-up achieved was approximately 12.6 months (SD 8.0).

TABLE 4

Comparison of Patients by Garden Classification: Displaced Versus Nondisplaced

	Garden classification				
Description	**n**	**Displaced**	**n**	**Nondisplaced**	***P***
Patient characteristics, n (%)		10 (22.7)		34 (77.3)	
Pauwels angle	10		34		
Type 1 or 2		0 (0)		28 (82.4)	**<0.001**
Type 3		10 (100)		6 (17.6)	
Fracture level					
Subcapital		0 (0)		26 (76.5)	**<0.001**
Transcervical		7 (70)		8 (23.5)	
Basicervical		3 (30)		0 (0)	
Reduction					
Acceptable		10 (100)		33 (97.1)	>0.999
Unacceptable		0 (0)		1 (2.9)	
Mean (SD) age at time of surgery		62.8 (20.2)		72.1 (12.6)	0.084
Mean (SD) BMI		27.6 (5.6)		25.3 (5.7)	0.257
Mean (SD) tip-to-apex distance; mm		25.7 (7.2)		25.0 (7.6)	0.800
Mean (SD) intraoperative blood loss		91.0 (63.3)		70.3 (46.0)	0.258
Median (IQR) surgical duration (min)*		36.0 (27.0, 81.0)		34.5 (26.0, 44.0)	0.475
Mean (SD) length of hospital stay; d		4.5 (2.4)		4.4 (2.6)	0.900
Mean (SD) follow-up time: number of days from date of surgery to date of last XR	10	340.9 (125.1)	34	399.9 (265.5)	0.524
Surgical outcomes					
Discharged status	10		34		
Home		4 (40)		17 (50)	0.207
Home with home health		1 (10)		3 (8.8)	
Skilled nursing (facility, unit, swing bed)		4 (40)		8 (23.5)	
Rehabilitation center		0 (0)		6 (17.6)	
Specialty hospital		1 (10)		0 (0)	
Fracture healing status (patients may have experienced more than one)					
Achieved fracture union with a healed fracture site		4 (40)		29 (85.3)	**0.008**
Achieved bony callous formation		1 (10)		1 (2.9)	0.407
Malunion		1 (10)		2 (5.9)	0.548
Nonunion		4 (40)		0 (0)	**0.002**
Did patient have any fracture complications?		5 (50)		7 (20.6)	0.105
Patients with postoperative complication (patients may have experienced more than one)					
Implant cutout		1 (10)		2 (5.9)	0.548
Avascular necrosis		2 (20)		3 (8.8)	0.317
Painful hardware		0 (0)		1 (2.9)	>0.999
Intractable pain due to wear of the acetabulum		1 (10)		2 (5.9)	0.548
Periprosthetic femur fracture		0 (0)		1 (2.9)	>0.999
Nonunion		4 (40)		0 (0)	**0.002**
Patients who required a reoperation					
Implant exchange: total hip arthroplasty		4 (40)		3 (8.8)	**0.037**
Implant exchange: hemiarthroplasty		0 (0)		2 (5.9)	>0.999
Implant exchange: internal fixation		0 (0)		1 (2.9)	>0.999
30-d readmission†					
Yes		0 (0)		3 (8.8)	>0.999
No		10 (100)		31 (91.2)	
Follow-up assessments					
Median (IQR) number of days between surgery and HOOS assessment*	8	362.5 (147.5, 406.5)	19	327 (194, 485)	0.915
Mean (SD) SF-12 Mental Health (raw score)	8	17.8 (6.7)	19	20.8 (4.1)	**0.015**
Mean (SD) SF-12 Physical Health (raw score)‡	8	11.4 (2.5)	19	14.7 (4.5)	**0.021**
Mean (SD) VAS pain score	8	3.4 (3.2)	19	1.8 (3.0)	0.244
Mean (SD) symptoms subscale score	8	61.3 (24.5)	19	76.6 (25.6)	0.163
Mean (SD) pain subscale score	8	66.6 (27.7)	19	79.1 (29.0)	0.310
Mean (SD) daily living subscale score	8	62.5 (21.3)	19	76.7 (27.4)	0.204
Mean (SD) sports and recreation subscale	6	39.6 (41.0)	16	66.4 (36.5)	0.153
Mean (SD) quality-of-life subscale score	8	31.3 (26.7)	19	67.4 (30.7)	**0.008**
Mean (SD) total WOMAC (0 = best, 96 = worst)	8	34.8 (21.2)	19	22.3 (26.0)	0.242

Bold indicates significance set at value of $P < 0.05$.
Results for mean comparisons are from the independent-samples *t* test with equal variances unless otherwise stated.
Mean (SD): mean and SD; median (IQR): median and interquartile range.
Results for frequencies and percentage comparisons are from the Fisher exact test.
* Mann–Whitney *U* test exact test.
† Adverse events (patients may have experienced more than one event): cardiovascular (1), pulmonary (1), decreased cognitive ability (1), neurological (1), renal (1), urinary (2), and others (3).
‡ Equal variances not assumed.

Patients sustained a 22% rate of inpatient medical adverse events with a 30-day readmission rate of 9%. Increasing BMI was associated with increased revision rates ($P = 0.037$). Patients who sustained displaced femoral neck fractures demonstrated significant decreases in SF-12 Mental Health Composite score (MCS), SF-12 PCS, and quality-of-life subscale scores.

4.2. Limitations

The findings of this study were limited by the feasibility and retrospective study design. While this study had broad inclusion criteria leading to a variety of patients and fracture characteristics, ultimately the participating surgeons were from a single institution and geographic location. The study was limited by a high dropout rate because most of the retrospective clinical follow-ups occurred during the COVID-19 pandemic, when some patients were reluctant to return for follow-up care. No power analysis was conducted to detect a change in the subgroup analyses because this is a novel implant with increasing usage in our facility. Other limitations included the retrospective nature of the study, unblinded patients and study personnel, and no control groups to compare types of internal fixation.

4.3. Interpretation

Hip fractures are associated with significant morbidity and mortality and caregiver burden. Reich et al[9] investigated the effect of routine follow-up for all low-energy hip fractures treated surgically and found that 1.7% of postoperative images and 4.5% of postoperative visits resulted in treatment changes at a median follow-up length of 54 days. Among patients with treatment changes, 77.4% had concerns that were initiated by the patient and/or their care provider.[9]

Over the 10-year period from 2003 to 2013, the incidence of femoral neck fractures decreased from 242 to 146 per 100,000 US adults while the proportion receiving operative management increased.[11] In addition, the study investigators Ju et al[11] found that the proportion of fractures treated with internal fixation remained relatively constant at approximately 29%, whereas those treated with hemiarthroplasty decreased from 65.1% to 63.6% ($P < 0.001$) and the cases managed with total hip arthroplasty increased from 5.9% to 7.4% ($P < 0.001$). Although there is still considerable debate regarding the optimal method of treatment for femoral neck fractures, there will likely continue to be a role for internal fixation in select patients.

This study showed comparable revision rates with those of published outcomes on internal fixation. A large multicenter randomized controlled trial, the FAITH trial, investigated low-energy patients with hip fracture aged 50 years who underwent internal fixation with SHS or CS. They found no difference in reoperation rates at 24 months (20% of SHS vs. 22% of CS), higher rates of avascular necrosis (AVN) with SHS (9% vs. 5%, $P = 0.032$), and similar implant failure rates (8%).[12] Internal fixation of femoral neck fractures is associated with a persistently high rate of revision surgery. In a multicenter, retrospective cohort study, Collinge et al reported that a major complication and/or major reconstructive surgery occurred in 45% of 492 patients younger than 50 years who underwent internal fixation. The rate was 52% among the 377 displaced fractures and 21% among 115 nondisplaced fractures. Patient complications included a rate of 23% nonunion/failure of fixation, 12% osteonecrosis type 2b or worse, 15% malunion (>10 mm), and 32% requiring major reconstructive surgery.

The FAITH investigators reported on the factors associated with increased risk of revision surgery including female sex ($P = 0.001$), higher body mass index ($P = 0.027$), displaced fracture ($P < 0.001$), unacceptable quality of implant placement ($P < 0.001$), and smokers treated with cancellous screws versus smokers treated with a sliding hip screw ($P = 0.006$).[13] This study found that increasing BMI (30.4 vs. 24.5, $P = 0.037$) significantly increased the risk of revision surgery. In addition, no significant difference in revision surgery rates was found among patients with displaced fractures compared with nondisplaced (40% vs. 17.6%, $P = 0.199$). Analysis of all other patient and fracture characteristics showed no significant difference between cohorts.

Stoffel et al[14] prospectively followed 125 patients who underwent FNS fixation for a variety of intracapsular femoral neck fracture types and found a treatment-related adverse event rate of 6.4% (95% CI, 2.8–12.2) at 3 months and 8.8% (95% CI, 4.5–15.2) at 12 months. In this study, patients sustained higher rates of revision surgery, especially for avascular necrosis. There is significant heterogeneity among FNS studies regarding how complications are reported. For example, Stoffel et al reported no instances of avascular necrosis while this study found that 40% of our surgical revisions were secondary to AVN of the femoral head. The investigators allowed patient dropout for fracture union without pain leading to a final 12-month analysis of 21 patients from the 125 who were enrolled, which could have resulted in different complication characteristics than a patient cohort with a mean follow-up of more than 12 months.

Multiple studies support FNS as an option for adult femoral neck fractures citing lower complication rates and better clinical outcomes.[10,14–16] Patel et al[16] recently published a meta-analysis of 8 studies containing 509 cases with a mean patient age of 50.8 years. The authors found that FNS fixation compared with cannulated screws had significantly reduced complication rates ($P < 0.001$), decreased incidence of postoperative femoral neck shortening ($P < 0.001$), shorter time to fracture union ($P = 0.002$), and better functional outcome scores ($P < 0.001$).

Scheutze et al[10] investigated 221 patients who sustained Garden I–IV fractures that underwent osteosynthesis with either FNS or SHS. The investigators found decreased hemoglobin differences ($P < 0.05$), shorter operative time ($P < 0.05$), and shorter hospital stays ($P < 0.05$). No differences between groups were observed regarding surgical complications (FNS 13.3% vs. SHS 18.4%, $P > 0.05$), rate of cutout (FNS 12.4% vs. SHS 10.2%, $P > 0.05$), and mortality (FNS 3.5%; SHS 0.9%; $P > 0.05$). The authors reported a logistic regression which showed that the poor blade position increased the risk of cutout by a factor of 7 and was a significant predictor of failure.[10]

Cintean et al[15] investigated patients who sustained Garden I (nondisplaced) hip fractures and surgical fixation with either hemiarthroplasty or FNS. The authors reported that FNS had significantly higher Charité Mobility Index, shorter hospitalization stays, less nonsurgical complications, shorter ICU stays, and less blood transfusions compared with hemiarthroplasty.[15] Internal fixation with FNS may provide patients with a faster perioperative recovery compared with endoprosthesis.[15]

4.4. Generalizability

Patient inclusion in the study was not limited by age, comorbidities, or intracapsular fracture type. This is a novel implant that requires more investigation and randomized trials.

5. Conclusions

FNS is a viable alternative for internal fixation of intracapsular femoral neck fractures. This study found rates of revision that were comparable with previously published outcomes following fixation with cannulated screws and sliding hip screws and recently published outcomes on FNS. Increasing BMI was associated with higher rates of revision surgery. Patients with unstable femoral neck fractures had significantly worse quality-of-life scores at the final follow-up.

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