Treatment Failure After Repair of Displaced Femoral Neck Fractures in Patients Compared by "Decade of Life": An Analysis of 565 Cases in Adults Less Than 60 years of Age

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OBJECTIVES: To study the results of displaced femoral neck fractures (FNFs) in adults less than 60 years of age by comparing patients, injury, treatment, and the characteristics of treatment failure specifically according to patients' age at injury, that is, by their "decade of life" [ie, "under 30" (29 years and younger), "the 30s" (30–39 years), "the 40s" (40–49 years), and "the 50s" (50–59 years)].

METHODS:

Design: Multicenter retrospective comparative cohort series.

Setting: Twenty-six North American Level 1 Trauma Centers.

Patient Selection Criteria: Skeletally mature patients aged 18–59 years with operative repair of displaced FNFs.

Outcome Measures and Comparisons: Main outcome measures were treatment failures (fixation failure and/or nonunion, osteonecrosis, malunion, and the need for subsequent major reconstructive surgery (arthroplasty or proximal femoral osteotomy). These were compared across decades of adult life through middle age (<30 years, 30–39 years, 40–49 years, and 50–59 years).

RESULTS: Overall, treatment failure was observed in 264 of 565 (47%) of all hips. The mean age was 42.2 years, 35.8% of patients were women, and the mean Pauwels angle was 53.8 degrees. Complications and the need for major secondary surgeries increased with each increasing decade of life assessed: 36% of failure occurred in patients <30 years of age, 40% in their 30s, 48% in their 40s, and 57% in their 50s ($P < 0.001$). Rates of osteonecrosis increased with decades of life (under 30s and 30s vs. 40s vs. 50s developed osteonecrosis in 10%, 10%, 20%, and 27% of hips, $P < 0.001$), while fixation failure and/or nonunion only increased by decade of life to a level of trend ($P = 0.06$). Reparative methods varied widely between decade-long age groups, including reduction type (open vs. closed, $P < 0.001$), reduction quality ($P = 0.030$), and construct type (cannulated screws vs. fixed angle devices, $P = 0.024$), while some variables evaluated did not change with age group.

CONCLUSIONS: Displaced FNFs in young and middle-aged adults are a challenging clinical problem with a high rate of treatment failure. Major complications and the need for complex reconstructive surgery increased greatly by decade of life with the patients in their sixth decade experiencing osteonecrosis at the highest rate seen among patients in the decades studied. Interestingly, treatments provided to patients in their 50s were notably different than those provided to younger patient groups.

KEY WORDS: femoral neck fracture, young, age, decade, failure

LEVEL OF EVIDENCE: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

Displaced femoral neck fractures (FNFs) are common injuries, and, in general, dogma favors joint replacement for the elderly and repair for young patients.[1–11] The rationale for arthroplasty in geriatric patients is that outcomes of repair are negatively affected by osteoporosis, inability to protect weight bearing, and other reasons.[12–14] Hip arthroplasty, on the other hand, is relatively contraindicated in younger patients due to potential restrictions in activity and the shortcomings of revision arthroplasties in later life.[15] A recent study evaluating outcomes of 477 FNFs in young patients <50 years of age using a similar database found that nearly half of patients experienced treatment failure, and risk factors for those failures were established. To date, no studies have investigated similar outcomes specific to age in young or middle-aged groups. "Optimal" treatment in the middle-aged population for this injury has not been established; thus, treatment with arthroplasty versus repair seems potentially arbitrary and largely subjective. The goal of this study was to investigate the patient, injury, and treatment characteristics and risk factors for treatment failure in a sizable cohort of patients aged 18–59 years with displaced FNFs treated with internal fixation with particular attention to the patient's age.

METHODS

Inclusion Criteria and Data Collection

Patients with FNFs [Orthopaedic Trauma Association (OTA/AO) type 31B fractures][16] from 26 North American Level 1 Trauma Centers were evaluated as part of this study. Patient ages ranged from 18 to 59 years, and their injuries were treated with surgical repair between January 1, 2005, and December 31, 2017. Institutional Review Board approval was obtained from each applicable center. Institutional databases were filtered for Current Procedural Terminology codes 27235 (femoral neck cannulated screw fixation) and 27236 [open reduction internal fixation (ORIF) hip fracture and hemiarthroplasty].[17]

Exclusion criteria included follow-up less than 6 months (unless the initial treatment failed), lack of adequate records or radiographic images for appropriate evaluation, initial treatment with arthroplasty or fixed-angled plates other than a sliding hip screw (SHS), skeletal immaturity, stress fracture, patients without a native contralateral hip, ballistic injury, nondisplaced fractures, and associated acetabular, femoral head, peritrochanteric fractures, or hip dislocations.

Medical records were reviewed, and data detailing patient characteristics, injury factors, and clinical outcomes were collected. Medical conditions associated with altered bone metabolism and fracture healing were identified,[18,19] which included smoking, diabetes mellitus type 1, chronic alcohol misuse, chronic steroid use, end-stage renal disease, and other metabolic diseases (including chronic liver, bone metabolism, or autoimmune diseases). All available radiographic imaging of the hip, pelvis, and femur from before ("injury"), during ("intraoperative"), and after surgery (including follow-up) was evaluated by 2 fellowship-trained orthopedic trauma surgeons; disagreements were adjudicated by a third orthopedic trauma surgeon. Initial fracture displacement was closely evaluated and classified (modified Garden classification,[20] modified Pauwels classification,[19,21] and the Orthopaedic Trauma Association's fracture classification).[16] Information regarding surgical approach (open vs. closed reduction), reduction quality, and implant(s) type was recorded. The quality of fracture reduction[5] was graded as excellent (<2 mm of displacement and <5 degrees of angulation in any plane on any view), good (2–5 mm of displacement and/or 5–10 degrees of angulation), fair (>5–10 mm of displacement and/or >10 degrees–20 degrees of angulation), or poor (>10 mm of displacement and/or >20 degrees of angulation or any varus). All measurements including shortening were estimated by comparing existing implant geometry (ie, screw head or SHS barrel diameter) and radiographic implant measures to control for magnification. Initially, a modified overlay technique was used to approximate the degree of vertical shortening as compared with the framework of the uninjured, contralateral hip[22–25]: a blueprint of the contralateral femoral head, neck, and trochanter was superimposed onto the radiograph being evaluated for FNF shortening. Next, the amount of implant shortening was measured by screw protuberance from the lateral cortex or changes in the SHS screw–barrel relationship.[25–27]

Treatment failure was the primary clinical outcome, and this was further explored by dividing it into the following categories: nonunion and/or failed fixation was defined as lack of healing at >6 months and/or loss of mechanical integrity with respect to the implant,[5,6] osteonecrosis as evaluated according to the modified Ficat system with types 2b and greater defined as clinical failures,[28] malunion defined as vertical or femoral neck shortening of ≥15 mm,[9,25–27] subsequent major reconstructive surgery defined as secondary conversion to hip arthroplasty or proximal femoral osteotomy.

Technical errors (TEs) were considered deviations from benchmark standards for repairing hip fractures and were defined as follows: "inadequate reduction" (graded fair or poor) according to the system described by Haidukewych,[5] fixed-angled devices (eg, SHS) with a tip–apex distance >25 mm,[29] multiple cannulated screw constructs with any of the following[30–34]: "inadequate buttress screw" defined as inferior calcar screw ≥4 mm away from the intramedullary cortical border of the intact inferomedial cortex of the shaft fragment, inadequate screw depth in the femoral head, and "inadequate screw spread" in the femoral head (<15 mm between screw shafts) on AP and lateral hip radiographs.

Statistics

All analyses were conducted using R studio version 2022.07.1 and CSBSJU stat pages[35] with the exception of the initial reporting of patient and fracture characteristics (Tables 1 and 2). Descriptive statistics of frequency and percent for categorical variables and mean ± SD was reported for patient, injury, and treatment/clinical results variables, overall and for patients of each decade of life separately—patients aged "under 30" (29 years and younger), "the 30s" (30–39 years), the "40s" (40–49 years), and the 50s (50–59 years). *P*-values were calculated using analysis of variance testing, and $P < 0.05$ was used to establish significance.

RESULTS

Patients

The study group comprised 565 patients with displaced FNFs treated with surgical repair: 97 patients were under 30 years of age, 130 in their 30s, 168 in their 40s, and 170 in their 50s. The mean duration of follow-up was 21 months but ranged from 0 weeks (early failure) to 141 months. Overall, the mean age was 42.2 ± 11.1 years, 35.8% of patients were women, and the mean Pauwels angle was 53.8 degrees.

TABLE 1. Patient, Injury, and Treatment Characteristics for Displaced Fractures in All Patients, Patients in the Second or Third Decade (16–29 y), Fourth Decade (30–39 y), Fifth Decade (40–49 y), and Sixth Decade (50–59 y) of Life

Variable	Entire Cohort	16–29 y	30–39 y	40–49 y	50–59 y	P
No. of patients with displaced fractures (n)	565	97	130	168	170	N/A
Mean age, y	42.2 ± 11.1	24.4 ± 3.3	34.9 ± 2.8	44.9 ± 2.7	54.2 ± 2.8	<0.001
Female	202 (35.8%)	32 (32.6%)	47 (35.9%)	50 (29.7%)	73 (42.6%)	<0.001
Mean body mass index (BMI) ± SD	26.7 ± 6.3	26.5 ± 8.0	26.5 ± 6.3	27.8 ± 5.9	26.0 ± 5.7	0.081
Metabolic bone conditions, total	269 (47.6.5%)	44 (45.3%)	67 (52.3%)	82 (49.1%)	76 (45.5%)	0.29
Current smoker	207 (37.3%)	35 (36.8%)	52 (40.6%)	68 (41.2%)	52 (31.1%)	
Diabetes mellitus	36 (6.5%)	3 (3.2%)	4 (3.1%)	9 (5.5%)	20 (12.0%)	
Current alcohol abuse	64 (11.5%)	9 (9.5%)	8 (6.3%)	30 (18.2%)	17 (10.2%)	
Current steroid use	19 (3.4%)	1 (1.1%)	5 (3.9%)	4 (2.4%)	9 (5.4%)	
End-stage renal disease	7 (2.7%)	0 (0%)	4 (3.1%)	2 (1.2%)	1 (0.6%)	
Mean modified Pauwels angle[14]	53.8 ± 11.4	55.4 ± 11.7	51.9 ± 10.8	53.1 ± 1.2	54.7 ± 11.8	0.08
Pauwels classification						0.506
Type I (<30 degrees)	10 (1.8%)	1 (1.1%)	3 (2.3%)	3 (1.8%)	3 (1.8%)	0.915
Type II (30°–50 degrees)	185 (33.3%)	23 (24.2%)	45 (35.2%)	60 (36.4%)	57 (34.1%)	0.214
Type III (>50 degrees)	364 (64.7%)	72 (74.7%)	81 (62.5%)	103 (61.8%)	109 (63.7%)	0.160
OTA classification (Type31B_._)[16]						0.008
1	67 (11.9%)	8 (8.4%)	12 (9.4%)	18 (10.9%)	28 (16.8%)	
2	452 (80.4%)	76 (78.9%)	102 (78.9%)	141 (84.2%)	133 (78.4%)	
3	46 (8.1%)	14 (12.6%)	16 (11.7%)	8 (4.8%)	8 (4.8%)	
Comminuted fractures	336 (60.5%)	66 (69.5%)	79 (61.7%)	109 (66.1%)	82 (49.1%)	<0.001
Associated femoral shaft fracture	91 (16.4%)	35 (36.8%)	24 (18.8%)	31 (18.8%)	1 (0.6%)	<0.001
Reduction method						
Closed	231 (40.9%)	17 (17.9%)	35 (27.3%)	72 (43.6%)	101 (60.5%)	<0.001
Open	334 (59.1%)	78 (82.1%)	93 (72.7%)	93 (56.4%)	66 (39.5%)	
Reduction quality[5]						
Excellent + good	476 (44.3%)	85 (89.5%)	115 (89.8%)	145 (87.9%)	141 (78.4%)	0.030
Fair + poor	79 (2.9%)	10 (10.6%)	13 (10.2%)	20 (12.1%)	36 (21.2%)	
Construct type						
Fixed-angled devices	260 (46.0%)	46 (47.4%)	74 (56.3%)	77 (45.5%)	63 (38.3%)	0.024
Sliding hip screws	238 (42.0%)	38 (40.0%)	65 (50.8%)	70 (42.4%)	61 (36.5%)	0.100
Cephalomedullary nails	22 (4.0%)	8 (8.4%)	7 (5.5%)	5 (3.0%)	2 (1.2%)	0.024
Multiple cannulated screws	305 (54.0%)	50 (52.6%)	57 (43.8%)	91 (54.5%)	107 (62.9%)	0.017
No. of technical errors (total)	252 (45.4%)	44 (46.3%)	57 (44.5%)	79 (47.9%)	72 (56.9%)	0.842
1	193 (34.8%)	34 (35.8%)	52 (40.6%)	61 (37.0%)	46 (27.5%)	0.105
2	59 (10.6%)	10 (10.5%)	5 (3.9%)	18 (10.9%)	22 (13.2)	0.605
3	0	0	0	0	4 (2.4%)	0.016

Additional patient and injury characteristics are presented in Table 1. Regarding patient, injury, and treatment factors, the 50s group had fewer fractures with comminution (49% vs. 61%, $P < 0.001$), were least likely to be treated with open reduction (40% vs. 60%, $P < 0.001$), and were more likely to be women (43% vs. 36%, $P < 0.001$) than patients in their 40s or younger.

Treatment Results

Treatment failure occurred in 47% of hips, and treatment failure rates overall increased with each later decade of life (36% vs. 40% vs. 48% vs. 57% reported from the youngest to the oldest group, $P < 0.003$). Patients studied who were in their 50s were more likely to experience *nonunion* (57% vs. 45%, $P = 0.030$) than those in the younger patient groups, but the differences in nonunion between the groups studied by decade were found only to be a trend ($P = 0.060$). These older patients were also treated with multiple cannulated screws (CSs) more frequently (compared with FA devices) than the younger groups (62% vs. 54% for CSs, $P < 0.017$; 38% vs. 46% for FA devices, $P < 0.024$). Finally, an analysis of variables by decade of life relative to failure is presented in Table 3. Variables showing characteristic increases of failure with advancing age are presented in Figure 1.

DISCUSSION

This study found that the rate of treatment failure after repair of 565 displaced FNFs in patients was high overall at 47%, but increased incrementally by decade of life for adults less than 60 years of age: 36% under age 30, 40% in their 30s, 47% in their 40s, and 57% in their 50s. This represents an increase in treatment failure of approximately 10% per decade

TABLE 2. Clinical Results and Complications for Displaced Fractures in All Patients, Patients in the Third Decade and Under (16–29 y), Fourth Decade (30–39 y), Fifth Decade (40–49 y), and Sixth Decade (50–59 y) of Life

	Entire Cohort	16–29 y	30–39 y	40–49 y	50–59 y	*P*
No. of patients (n)	565	97	130	168	170	N/A
Hips with major complications and/or subsequent reconstructive surgery	264 (46.7%)	35 (36.1%)	52 (40.00%)	81 (48.2%)	96 (56.5%)	0.003
Nonunion and/or catastrophic failed fixation, or both	171 (30.3%)	23 (23.7%)	34 (26.2%)	50 (29.8%)	64 (37.6%)	0.060
"Severe" osteonecrosis (≥type 2B)[29]	102 (18.1%)	10 (10.3%)	13 (10.0%)	34 (20.0%)	45 (26.5%)	<0.001
"Malunion" defined as ≥15 mm	35 (6.2%)	2 (2.1%)	12 (9.4%)	7 (4.2%)	13 (7.8%)	0.077
Patients having secondary surgery(ies)	238 (42.9%)	39 (41.1%)	51 (39.8%)	91 (55.2%)	57 (34.1%)	<0.001
"Major reconstructive surgery"	194 (35.1%)	31 (32.6%)	40 (31.3%)	70 (42.6%)	51 (30.5%)	0.045
Early revision fixation	9 (1.6%)	0 (0.0%)	2 (1.6%)	6 (3.6%)	1 (0.6%)	
Hip arthroplasty	143 (25.8%)	17 (17.9%)	27 (21.1%)	51 (30.9%)	48 (28.7%)	
Proximal femoral osteotomy	46 (8.3%)	13 (13.7%)	13 (10.2%)	18 (10.9%)	2 (1.2%)	
"Minor secondary surgery" (Total)	42 (7.6%)	7 (7.4%)	10 (7.8%)	20 (12.1%)	5 (3.0%)	0.013
Removal of hardware	29 (5.2%)	4 (4.2%)	6 (4.7%)	15 (9.1%)	4 (2.4%)	
Debridement for deep infection	2 (0.4%)	0 (0.0%)	1 (0.8%)	1 (0.6%)	0 (0.0%)	
Screw exchange	6 (1.1%)	0 (0.0%)	2 (1.6%)	3 (1.8%)	1 (0.6%)	

after age 30 to age 60. Prior studies have largely focused on either "elderly" or "young" patients, but age-related failures of FNFs in young and middle age have not been adequately investigated.[1–14] In a previous study using a portion of this database, age was found to increase the relative risk for treatment failure in young patients <50 years of age, but the multivariate analysis showed a significant OR of only 1.03 in the univariate analysis and none in the multivariate examination. Other factors carried a greater and significant multivariate OR for failure including inadequate fracture reduction (OR 4.0, $P = 0.002$), femoral neck comminution (OR 2.2, $P = 0.003$), and repair with CSs [vs. use of an FA construct (2.0, $P = 0.001$)]. There may be other causes explaining increasing failure rates for repaired FNFs while advancing into middle age. Patient demographics, injury patterns, and treatments changed with increasing age, including decreasing rates of fracture comminution and associated shaft fractures (both *P*s < 0.001), open reductions ($P < 0.001$), reduction quality ($P = 0.030$), use of a fixed-angled device ($P = 0.024$), and an increasing number of TEs ($P = 0.016$, Table 1).

Notably, even though the treatment failure rate increased with age, not all modes of failure increased equally. Osteonecrosis closely mimicked the overall failure rate (Table 2), while the rates of failed fixation/nonunion and malunion only trended to significance in the analysis by age groups. The failure mode of nonunion/failed fixation is not an unexpected risk in these patients and among our age groups was seen increasing from 36%, 40%, 48%, to 57%. It seems logical that lesser bone quality may negatively affect a surgeon's ability to stabilize an FNF, perhaps especially given the potential factors involved, such as a short, relatively osteopenic segment that is acted on by powerful forces and bicortical screw fixation is contraindicated. The rate of osteonecrosis increased in these patients by decade of life from approximately 10% in the groups under 40 years of age to 20% and 27% in the 40s and 50s groups, respectively. The rationale for this finding may not be as obvious. One might propose that decreasing the quality of reduction and fixation (as indicated earlier) may not allow for optimal biology or revascularization of these intraarticular fractures with precarious blood supply. Interestingly, the incidence of malunion did not increase by decade. The overall rates of metabolic bone conditions (smoking, diabetes, alcohol use, steroid use, and end-stage renal disease) did not appear to vary widely between groups, and the incidence of patients reported as smokers and alcohol misusers diminished in middle age compared with younger patients. It is also notable that the proportion of patients treated who reported steroid and alcohol use, established risk factors for osteonecrosis, was generally higher in the older groups studied. This disparity may contribute to the higher rate of osteonecrosis seen in these older groups.[28]

Although the rate of fracture increased in patients in the later decades studied, age alone, or even in combination with other factors, does not seem like a dependable predictor of treatment failure. In this study, the *number of patients* treated for displaced FNFs with repair increased with age but plateaued in the age 50s group, where presumably patients with this injury were considered reasonable candidates for arthroplasty. The increased occurrence of FNFs is well recognized in the elderly population.[1–14] Peak bone mass occurs around age 25 years or so, followed by a variable decline through the rest of adult life.[36] Furthermore, in the groups studied, the rate of female patients appeared to be 7%–13% higher in patients in their 50s. Women in this decade are potentially postmenopausal and thus may be exhibiting accelerated bone loss. Interestingly, the number of patients identified as having metabolic bone problems expected to affect fracture risk did not increase overall with age, although the severity of these conditions or their effect on bone density or fragility was not evaluated in this study. While rates of metabolic bone disease were not seen to increase, fracture patterns were notably different, as were rates of associated femoral shaft fractures. Comminution was seen at similarly high rates in patients in the youngest groups as compared with patients in their 50s. An explanation for these findings could be based on the mechanism of injury, that is, younger patients potentially sustaining higher energy trauma.[36] Mechanism of injury is

TABLE 3. Clinical Data for Patients With Displaced Fractures, Under 30 Years of Age (16–29 y), in the Fourth Decade (30–39 y), in the Fifth Decade (40–49 y), and Sixth Decade (50–59 y) of Life

Variable	Entire Cohort	16–29 y	30–39 y	40–49 y	50–59 y	*P*
No. of patients (n)	563	95	128	165	167	N/A
Hips with major complications and/or subsequent reconstructive surgery	261 (45.7%)	35 (33.7%)	48 (37.5%)	78 (47.3%)	100 (59.8%)	0.003
Mean age, y	41.9 ± 10.9	24.4 ± 3.3	34.9 ± 2.8	44.9 ± 2.7	54.2 ± 2.8	<0.001
Female	197 (35.5%)	31 (32.6%)	46 (35.9%)	49 (29.7%)	71 (42.5%)	<0.001
Mean body mass index (BMI) ± SD	26.7 ± 6.4	26.5 ± 8.0	26.5 ± 6.3	27.8 ± 5.9	26.0 ± 5.7	0.081
Metabolic bone conditions, total	269 (48.5%)	44 (45.3%)	67 (52.3%)	82 (49.1%)	76 (45.5%)	
Current smoker	207 (37.3%)	35 (36.8%)	52 (40.6%)	68 (41.2%)	52 (31.1%)	0.29
Diabetes mellitus	36 (6.5%)	3 (3.2%)	4 (3.1%)	9 (5.5%)	20 (12.0%)	
Current alcohol abuse	64 (11.5%)	9 (9.5%)	8 (6.3%)	30 (18.2%)	17 (10.2%)	
Current steroid use	19 (3.4%)	1 (1.1%)	5 (3.9%)	4 (2.4%)	9 (5.4%)	
End-stage renal disease	7 (2.7%)	0 (0%)	4 (3.1%)	2 (1.2%)	1 (0.6%)	
OTA classification (Type31B_._)[16]						
1	66 (11.9%)	8 (8.4%)	12 (9.4%)	18 (10.9%)	28 (16.8%)	0.008
2	446 (80.4%)	75 (78.9%)	101 (78.9%)	139 (84.2%)	131 (78.4%)	
3	43 (7.7%)	12 (12.6%)	15 (11.7%)	8 (4.8%)	8 (4.8%)	
Mean modified Pauwels angle[14]	53.8 ± 11.4	55.4 ± 11.7	51.9 ± 10.8	53.1 ± 1.2	54.7 ± 11.8	0.08
Pauwels classification						0.506
Type I (<30 degrees)	10 (1.8%)	1 (1.1%)	3 (2.3%)	3 (1.8%)	3 (1.8%)	0.915
Type II (30–50 degrees)	185 (33.3%)	23 (24.2%)	45 (35.2%)	60 (36.4%)	57 (34.1%)	0.214
Type III (>50 degrees)	359 (64.7%)	71 (74.7%)	80 (62.5%)	102 (61.8%)	106 (63.5%)	0.160
Comminuted fractures	336 (60.5%)	66 (69.5%)	79 (61.7%)	109 (66.1%)	82 (49.1%)	<0.001
Associated femoral shaft fractures	91 (16.4%)	35 (36.8%)	24 (18.8%)	31 (18.8%)	1 (0.6%)	<0.001
Reduction method						<0.001
Closed	225 (40.5%)	17 (17.9%)	35 (27.3%)	72 (43.6%)	101 (60.5%)	
Open	330 (59.5%)	78 (82.1%)	93 (72.7%)	93 (56.4%)	66 (39.5%)	
Reduction quality						
Excellent + good	476 (44.3%)	85 (89.5%)	115 (89.8%)	145 (87.9%)	141 (78.4%)	
Fair + poor	79 (2.9%)	10 (10.6%)	13 (10.2%)	20 (12.1%)	36 (21.2%)	0.030
Construct type:						
Fixed-angled devices	256 (46.1%)	45 (47.4%)	72 (56.3%)	75 (45.5%)	64 (38.3%)	0.024
Sliding hip screws	233 (42.0%)	38 (40.0%)	65 (50.8%)	70 (42.4%)	61 (36.5%)	0.100
Cephalomedullary nails	22 (4.0%)	8 (8.4%)	7 (5.5%)	5 (3.0%)	2 (1.2%)	0.024
Multiple cannulated screws	300 (54.1%)	50 (52.6%)	56 (43.8%)	90 (54.5%)	104 (62.3%)	0.017
No. of technical errors (total)	252 (45.4%)	44 (46.3%)	57 (44.5%)	79 (47.9%)	72 (56.9%)	0.842
1	193 (34.8%)	34 (35.8%)	52 (40.6%)	61 (37.0%)	46 (27.5%)	0.105
2	59 (10.6%)	10 (10.5%)	5 (3.9%)	18 (10.9%)	22 (13.2)	0.605
3	0	0	0	0	4 (2.4%)	0.016

a difficult factor to accurately study and represents a limitation of this investigation.

Important differences in the method of repair existed between the age groups studied. For example, the number of patients treated with multiple CSs increased with age compared with FA devices. In a 2014 survey of "expert" OTA members, Luttrell et al reported that surgeons' implant choices were arbitrary: the majority of surgeons reported that the most important reason for choosing an implant was "biomechanically stability," but half preferred an FA device and half CSs.[37] Other studies suggest that CSs have lower load-bearing capability, that is, greater susceptibility to failure but can be considered in the treatment of elderly populations because they are less invasive and/or protective of femoral head vascularity compared with FA devices.[38–41] In contrast to this theory, Hoshino et al reported on 62 patients with displaced FNFs undergoing repair aged 16–60 years and noted fewer failures (21% vs. 60%, P = 0.008) and lower rates of osteonecrosis (2% vs. 33%, P = 0.002) with the use of FA devices as compared with screws.[40,42] Other studies have reported similar preliminary findings, but they were either limited by small sample sizes or unable to deliver a conclusion that met the criteria for statistical significance.[1–14] Our study findings indicate that further research into this area is warranted with close regard to the identification of an evidence-based protocol for the selection of treatment devices for patients in their 50s given that these patients seem to be the most likely to receive treatment with CSs yet also have the highest failure and nonunion rates and the highest rate of osteonecrosis across all decades studied.

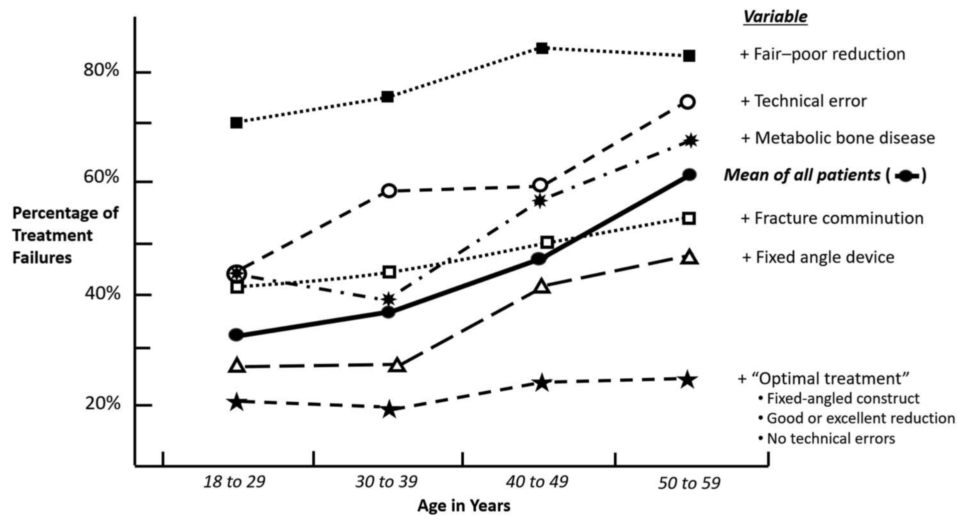

FIGURE 1. Graph of variables relative to failure by decade of life.

The treatment method chosen following treatment failure varied by decade as well. Remarkably, patients in their 50s were found to be least likely to undergo both major and minor secondary surgery despite having exhibited the highest rate of failure. There could be several potential reasons for this finding including a lack of additional follow-up, refusal of additional surgeries, presence of multiple medical comorbidities, lack of a home support system, or the presence of cost-related barriers to access. Studies also suggest that the results following conversion from ORIF to THA are suboptimal.[42,43] Despite such findings, THA remains highly regarded as a primary treatment method, especially in older patients, given the lower rates of reoperation, higher rate of success, and better functional outcomes than ORIF. Thus, initial findings suggest that middle-aged patients may benefit from additional surgical consideration to decide whether they may be better suited to undergo THA for primary treatment of FNFs given their high rate of failure with ORIF and low likelihood of undergoing subsequent reoperation.

Last, the incidence of TEs, including those arising from insufficient reduction, poor reduction quality, and improper device installation, was similar across patients in all decades of life. Despite this finding, patients in the 50s group exhibited more TEs per patient than the other groups. These patients' reduction qualities also met Haidukewych criteria of "fair" or "poor" more often than patients in the under 30s to the 40s group.[5] Although we are unable to conclude that there is a relationship between the number of TEs seen and patient age as the data in this category did not meet the criteria for significance, previous studies have highlighted the importance of TEs and their association with failure.[44,45] Collinge et al studied 492 FNFs in patients <50 years of age and found that treatment failure occurred in 27% of cases without a TE, 57% with 1 TE, 84% with 2 TEs, and 100% with 3 TEs ($P < 0.001$).[46] Thus, surgeons should maintain a high level of caution during repair and continue to keep themselves up to date with evidence-based guidelines.[47] This approach will likely optimize treatment success and minimize the risk of avoidable TEs to give the repair a fighting chance against failure.

Two questions might be asked: first, is age a good predictor for treatment failure? and second, at what age indicator should arthroplasty be strongly considered? Currently, survivorship of hip arthroplasties has improved, and more outcomes data are available for "young" patients with hip arthroplasty than ever before such that these patients may be subject to fewer and fewer activity restrictions. We authors advocate that these decisions be made on a case-by-case basis by the patient in collaboration with the surgeon after an exchange of information and education of both parties. The overall rate of treatment failure for all ages studied was 47% in these patients under age 60 with displaced FNFs. Beyond age, other important factors have been identified that are associated with failure, and many of these, including other patient, injury, and treatment factors, are discussed earlier. The effects of some of these factors are shown in Figure 1. Recent studies, including those from this database, have shown that more than a few of these factors are modifiable, and notably improved results might be expected for repairs that incorporate factors such as a high reduction quality, thoughtful implant selection, and a lack of TEs. Considering these other factors in the decision for repair versus arthroplasty seems imperative.[48]

This study has weaknesses. First, the patients studied were specifically selected to receive ORIF as primary treatment; thus, inherent biases are built into this study. Second, data used were collected from level 1 trauma centers across the United States, and as such it may not be representative of practices at community, rural, or international medical facilities. That said, even the so-called "experts" experienced a high rate of TEs in their implementation of these repairs. Third, we chose to define malunion as ≥15 mm, which is somewhat controversial.[25–28] Usage of other criteria may increase the incidence of treatment failure even higher than we reported. There are strengths to this study as well. First, we were able to study 565 FNFs in young and middle-aged patients treated at major level 1 trauma centers across North America. This large sample size has allowed our results to have power that has not been previously seen on similar topics.[1–14] Second, the treatment approaches used were subjectively consistent at the facilities studied with no identifiable outliers in the methodologies utilized. Third, we have clearly defined the types and methods of treatment failure and tried to use clinically relevant findings to facilitate categorization. Finally, we have analyzed several important risk factors for FNF treatment failure across patients in order of increasing age from the second to the sixth decade of life. Our findings may ultimately improve surgical decision making for middle-aged patients with displaced FNFs who have historically been treated arbitrarily with respect to the decision between arthroplasty and repair.

In summary, displaced FNFs in young and middle-aged adults result in a high rate of treatment failures. Major complications and the need for complex reconstructive surgery increased by decade of life with the patients in their sixth decade experiencing failed fixation/nonunion and osteonecrosis at the highest rate seen among patients. Prior regression analyses, however, indicate that age when considered in combination with other variables is not the paramount factor on which to base treatment decisions such as repair versus arthroplasty. It seems that considering the physiological age of patients rather than simply their chronological age would be a potentially more useful variable in decision making. The idea of using a breadth of patient, injury, and potential treatment information in decision making, including age or decade of life, appears supported by this large, multicenter study of young and middle-aged patients.

APPENDIX

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