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Low risk of nonunion with lateral locked plating of distal femoral fractures—A retrospective study of 191 consecutive patients

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ABSTRACT

Introduction: The reported rate of nonunion of distal femoral fractures varies in the literature. Several risk factors for nonunion following lateral locked plating (LLP) have been described. We aimed to study the rate of nonunion, and risk factors thereof, in a Swedish population where fragility fractures are common. A secondary aim was to study risk factors for reoperation for any cause.

Patients and Methods: We retrospectively reviewed the hospital files and radiographs of all adult patients admitted to our institution with a distal femoral fracture, from 2004 through 2013. In cases treated with LLP, medical comorbidities, fracture characteristics and implant characteristics were analysed as potential risk factors for nonunion, defined as any surgical intervention to improve healing.

Results: There were 8 cases (4%, 95%CI: 1.8–8.1%) of nonunion in 191 fractures treated with LLP. Patients with nonunion were younger: 62 vs. 81 years (p = 0.009) and more commonly had open fractures: 38% vs. 9% (p = 0.034). No patient 80 years or older had a surgical intervention for nonunion. Lower age was independently associated with reoperation for any cause, but not for nonunion.

Discussion: The low rate of nonunion in this study is probably due to the fact that we present data from a complete cohort from a geographic catchment area. Referral centres with a high proportion of young patients with high-energy injuries, may be better suited for studies on risk factors for nonunion, due to higher statistical power. However, results from such institutions may not be generalizable to the more common low-energy fractures.

Introduction

Fractures of the distal femur account for 0.7% of all fractures, and 5% of all femoral fractures [1]. They have a bimodal distribution, typically affecting young men as the result of high-energy trauma or elderly women after a low-energy fall [2]. The 1-year mortality in geriatric patients is 18–22% [3,4].

Nonunion rates up to 35% are reported from centres with a high proportion of high-energy injuries [5]. On the other hand, the intervention rate for nonunion was only 3% in a large consecutive cohort of predominantly elderly patients [4]. A recent large survey found that nonunion, in general, may be a less common problem than previously thought [6].

Apart from risk factors outside surgeon control, such as age, obesity, diabetes, infection and open fracture, the use of stainless-steel plates (compared to titanium plates), exclusive use of locking screws, high screw density and high assessed implant rigidity have been associated with increased rates of nonunion [5–10].

The primary aim of this study was to describe the rate of nonunion and risk factors thereof following lateral locked plating (LLP) in a large consecutive cohort of patients. Of special interest were plate material and the mechanical construct of the implant, as these factors are within the treating physician's control.

A secondary aim was to analyse risk factors for reoperation of any kind following LLP.

The study was approved by the local ethical board (LU 2014/793).

Patients and methods

All patients aged 16 years and older that had presented with a distal femoral fracture at our institution during the years 2004 through 2013 were eligible for study. Patients were identified through a diagnosis registry, including both in-hospital stays and outpatient visits at Skåne University Hospital, Malmö, Sweden.

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Fractures were radiographically classified according to the AO/OTA classification as AO/OTA type 33 A, B or C [11]. The presence of an implant in the knee, hip or both at the time of fracture was registered.

Patients not having an AO/OTA type 33 fracture (i.e. a wrongful entry in the diagnosis registry) and patients who sustained the fracture before 2004 were not included.

For fractures treated with LLP, data on plate material, plate length (in number of holes proximal to the condylar region, according to manufacturer's description), number of screws distal and proximal to the fracture respectively, bridge span (in number of empty holes between the distal and proximal screws) and proximal working length (in number of plate holes from the first through the last screw in the proximal fixation segment) was obtained from the radiographs (Fig. 1).

Patient characteristics at the time of fracture were obtained from hospital files, including data on age, gender, diabetes, number of medications, systemic corticosteroid treatment and treatment with dialysis. Information on weight, length and smoking was incomplete in many cases and was omitted from analysis. Patients with previous kidney transplantation, currently not undergoing dialysis, did not count as patients on dialysis. Data on fracture characterization in open or closed, the use of temporary external fixation and reoperations was also obtained from the hospital files. The observation time was >2 years in all cases.

The number of medications was calculated as pharmacological groups, so that for example a combination analgesic with acetaminophen and codeine counted as 2 medications, whereas two different inhalation corticosteroids counted as 1 medication. Inhalation corticosteroids were counted as systemic corticosteroid treatment. Two different diuretics were counted as two medications, unless both had the same pharmacological action (for example two loop diuretics which would count as one medication). Eye drops and skin preparations for local use were not counted.

Statistical comparisons of patient and fracture characteristics were performed with Fisher's exact test for categorical variables, or the Mann-Whitney *U* test for continuous variables. Logistic regression was performed to calculate adjusted odds ratios with 95% confidence intervals (95%CI) with all potential risk factors except dialysis (only 2 patients) included in the model. The alpha level for statistical significance of inferential statistics was set at 0.05. The 95%CI for nonunion rate was calculated using the exact binomial method. Statistical analyses were performed with IBM SPSS Statistics, version 21.0 for Mac (Armonk, NY: IBM Corp.) and Microsoft Excel for Mac 2011, version 14.2.3 (Redmond, WA: Microsoft Corp.).

Fig. 1. Example of how implant characteristics were counted. Radiograph taken 6 weeks postoperatively of a 73-year-old man treated for an open fracture engaging a pre-existing knee arthroplasty. A. There are 4 screws proximal to the fragment and 1 empty hole giving a proximal working length of 5. B. The bridge span equals 5 empty holes. C. There are 5 screws in the distal fragment. The plate length is 10 holes (the holes in A + B in this case).

Results

There was a total of 441 distal femoral fractures in 428 patients (10 bilateral fractures and 3 patients sustaining a fracture at two separate incidents). There were 338 (79%) female and 90 (21%) male patients. The median age was 79 years (mean: 74, range: 16–104). The age and gender distribution is given in Fig. 2. Roughly half of all fractures were AO/OTA class 33 A. 42% of the fractures had a previous implant in the hip, knee or both, with the frequency of pre-existing implants increasing with age (Table 1).

Of the 441 distal femoral fractures, 191 (43%) were operated with LLP, 134 (30%) were managed non-operatively, 55 (12%) had intramedullary nailing and 61 (14%) were treated with other surgical methods. There were 28 (6%) open fractures. 16 fractures (4%) had a temporary external fixator, 13 of these being open injuries.

The total reoperation rate after LLP was 38 (20%, 95%CI: 15–26%) of 191 fractures. 8 (4%, 95%CI: 1.8–8.1%) reoperations were due to nonunion, 12 (6%, 95%CI: 3.3–10%) reoperations were hardware removal due to local complaints, 3 (2%, 95%CI: 0.3–4.5%) were due to infection and 15 (8%, 95%CI: 4.5–13%) for other causes. Both the total reoperation rate and reoperations due to nonunion decreased with patient age (Fig. 3).

Patients with nonunion were younger: 62 vs. 81 years ($p = 0.009$), and more commonly had open fractures: 38% vs. 9% ($p = 0.034$) (Table 2). None of the examined variables proved to be an independent risk factor for nonunion in logistic regression analysis.

38 fractures were operated with titanium plates and 152 with stainless-steel implants. Data on implant characteristics was missing in one patient who died early postoperatively. The implant material did not correlate statistically with risk of nonunion or reoperation for any cause. The other studied implant characteristics were similar in patients who developed nonunion or were reoperated for any reason, and those who did not (Tables 2 and 3).

Patients undergoing any reoperation were younger, more commonly male, and more commonly had temporary external

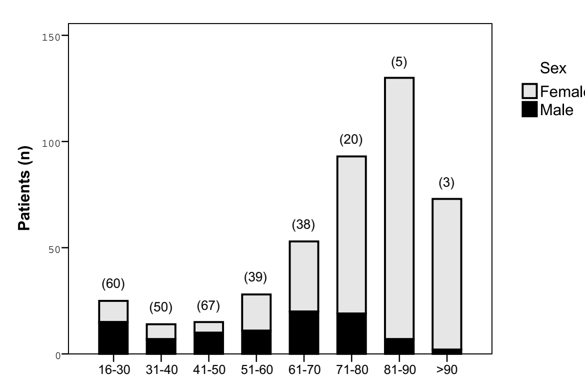

Fig. 2. Age and sex distribution in 428 patients presenting with a distal femoral fracture during the study period. The 3 patients presenting at two separate occasions are counted twice. The percentage of male patients in each age group is given within parentheses.

Table 1
Fracture distribution, according to the AO/OTA classification, in 441 distal femoral fractures, including the subgroup that underwent LLP. There were a total 107 (24%) pre-existing hip implants, 56 (13%) knee arthroplasties, plus 27 (6%) implants in both hip and knee at the time of injury. In patients 80 years or older, 56% had pre-existing implants in the fractured femur (35% hip, 13% knee, 8% both). AO/OTA class B fractures were less often operated with LLP, as these fractures can be managed with buttress plating without use of locking screws.

	Total cohort (441 fractures)		Lateral locked plating (191 fractures)	
AO/OTA class	No (%)	Pre-existing implant, no (%)	No (%)	Pre-existing implant, no (%)
A	235 (53%)	92 (39%) no implant	110 (58%)	34 (31%) no implant
		64 (27%) hip implant		33 (30%) hip implant
		54 (23%) knee arthroplasty		54 (27%) knee arthroplasty
		25 (11%) both hip and knee		13 (12%) both hip and knee
B	99 (22%)	80 (81%) no implant	18 (9%)	14 (78%) no implant
		24 (24%) hip implant		3 (17%) hip implant
		1 (1%) knee hemiarthroplasty		–
		–		1 (6%) both hip and knee
C	93 (21%)	71 (76%) no implant	63 (33%)	47 (75%) no implant
		19 (20%) hip implant		13 (21%) hip implant
		1 (1%) knee arthroplasty		2 (3%) knee arthroplasty
		2 (2%) both hip and knee		1 (2%) both hip and knee
Other[1]	14 (3%)	No implants	–	–

[1] "Other" fractures include avulsions from the femoral condyles, articular impactions and one femoral condyle osteochondral injury associated with a patellar dislocation.

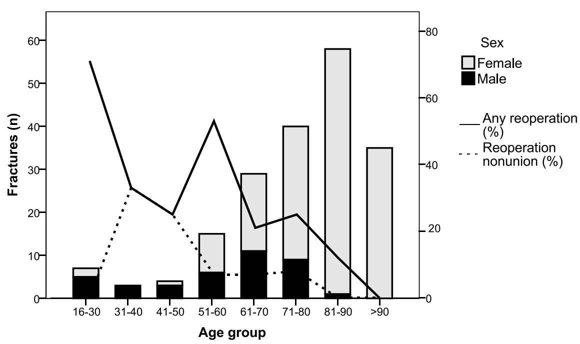

Fig. 3. Age and sex distribution in 191 distal femoral fractures (185 patients) treated with lateral locked plating (bars, left y-axis). The risk of reoperation for nonunion (dotted line) or any cause (line) is given for each age group (right y-axis).

fixation and open fractures. Pre-existing implants were less common in reoperated patients. A lower age was independently associated with reoperation, with each additional year reducing the odds ratio by 4% (95%CI: 1–7%) (Table 3).

Discussion

Fixation of distal femoral fractures using LLP was introduced in the late 1990-ies [12]. The use of LLP increased at our institution from only 4 cases in 2005 to 22–30 cases yearly during the last 5 years of the study. Although healing rates are high, some studies report reoperation to promote healing in 9%–13% of fractures, or 19% if planned staged bone reconstructions for segmental defects are included [7,10,12]. Using radiographic criteria, Harvin et al. reported a 35% nonunion rate [5]. The studies cited above report on substantially younger patient cohorts than the present one, with rates of open fractures ranging from 17% to 33%. In our cohort, with 6% open fractures, the risk for reoperation to promote healing was

Table 2
Patient, fracture and implant characteristics in 191 distal femoral fractures treated by lateral locking plate fixation. Cases that where reoperated for delayed union or nonunion are compared to cases that were not.

	Intervention for nonunion (n = 8)	No intervention (n = 183)	p-value
Age, years [1]	62	81	0.009
Female	5 (63%)	147 (81%)	0.20
Male	3 (38%)	36 (19%)	
Diabetes	2 (25%)	30 (16%)	0.62
Corticosteroids	2 (25%)	21 (12%)	0.25
Dialysis	0	2 (1%)	1
No of medications [1,2]	5	5	0.26
AO/OTA class			0.45
A	4 (50%)	106 (58%)	
B	0	18 (10%)	
C	4 (50%)	59 (32%)	
Pre-existing implant	2 (25%)	93 (51%)	0.28
External fixation	1 (13%)	11 (6%)	0.41
Open fracture	3 (38%)	16 (9%)	0.034
Titanium plate [3]	1 (13%)	37 (20%)	1
Stainless steel [3]	7 (88%)	145 (80%)	
Plate length, holes [1,3]	9.5	9	0.73
Distal screws, no [1,3]	5	5	0.68
Proximal screws, no [1,3]	4.5	4	0.82
Proximal working length, no [1,3]	5.5	6	0.97
Bridge span, no [1,3]	3.5	2	0.33

[1] Median value is given when data not normally distributed.
[2] Information uncertain on number of medications in 2 patients.
[3] Information missing on implant characteristics in 1 patient.

Table 3
Patient, fracture and implant characteristics in 191 distal femoral fractures treated by lateral locking plate fixation. Cases that where reoperated for any reason, including nonunion, are compared to cases that were not.

	Any reoperation (n = 38)	No intervention (n = 153)	p-value	Adjusted OR (95%CI)
Age, years[1]	65	83	<0.001	0.96 (0.93–0.99)
Female	23 (61%)	130 (85%)	0.002	0.98 (0.30–3.18)
Male	15 (40%)	23 (15%)		
Diabetes	4 (11%)	28 (18%)	0.33	0.67 (0.20–2.24)
Corticosteroids	4 (11%)	19 (12%)	1	0.68 (0.17–2.77)
Dialysis	1 (3%)	1 (1%)	0.36	
No of medications[2]	5	6	0.083	1.03 (0.92–1.16)
AO/OTA class			0.095	
A	18 (47%)	92 (60%)		
B	2 (5%)	16 (10%)		0.74 (0.12–4.38)[4]
C	18 (47%)	45 (29%)		0.85 (0.30–2.42)[4]
Pre-existing implant	11 (29%)	84 (55%)	0.006	0.60 (0.21–1.72)
External fixation	8 (21%)	4 (3%)	<0.001	2.41 (0.39–14.7)
Open fracture	11 (29%)	8 (5%)	<0.001	1.44 (0.29–7.22)
Titanium plate [3]	11 (29%)	27 (18%)	0.17	
Stainless steel [3]	27 (71%)	125 (82%)		0.39 (0.14–1.06)
Plate length, holes[1,3]	9.5	9	0.19	1.29 (0.98–1.69)
Distal screws, no[1,3]	5	5	0.29	0.90 (0.54–1.49)
Proximal screws, no[1,3]	4	4	0.22	0.88 (0.55–1.42)
Proximal working length, holes[1,3]	6	6	0.63	0.80 (0.57–1.11)
Bridge span, no[1,3]	3	2	0.097	0.85 (0.63–1.16)

[1] Median value is given when data not normally distributed.
[2] Information uncertain on number of medications in 2 patients.
[3] Information missing on implant characteristics in 1 patient.
[4] Compared to AO/OTA class A.

only 4%. No patient 80 years or older (n = 95) had an intervention for nonunion.

Through osteosynthesis and postoperative restrictions, the surgeon gains partial control over biomechanical forces at the fracture site. Such forces are important for the differentiation of periosteal progenitor cells in fracture healing [13]. A titanium implant will afford more motion under load compared to a stainless-steel implant of the same dimensions, due to the higher elastic modulus of titanium. In retrospective studies, titanium plates have been associated with larger callus volumes and a lower rate of nonunion [10,14,15]. Larger callus volumes correlated with increased longitudinal motion and decreased transverse motion in finite element analysis of simulated fracture-site motion [14]. Exclusive use of locking screws, high screw density and an implant rigidity score have also been associated with nonunion [5,9,10]. The concept that overly rigid osteosynthesis gives suboptimal conditions for healing is also supported by an experimental animal model [16]. We did not find an association between nonunion and any of the studied implant characteristics in this cohort of 191 plated fractures.

Why do elderly patients so seldom develop nonunion after LLP of a distal femoral fracture? There are several plausible explanations. High-energy trauma is rare in the elderly population. Therefore, soft tissues are less commonly severely traumatized. Secondly, an elderly patient will typically have a less active lifestyle, perhaps due to poor clinical outcome after fracture care, and will take longer time to wear the implant to fatigue failure if healing progresses slowly [3]. A third likely explanation is surgeon and patient bias against secondary surgery in frail patients with multiple medical comorbidities.

Our cohort consists of virtually all distal femoral fractures in a geographic area and our observed low rate of nonunion is probably closer to the “true” nonunion risk in an unselected population undergoing LLP [4,6]. Another strength of this study is the long observation time, which should be over 2 years as nonunion may present as late implant failure in some cases [17].

Limitations

The retrospective design of our study limits its usefulness for giving treatment recommendations.

Smoking, which is a known risk factor for nonunion was inadequately reported in our material, precluding analysis [18]. We also lacked complete data on patient body mass index, which has been described as a risk factor [8]. We would ideally have wanted to include them in the calculation of adjusted odds ratios.

The use of temporary external fixation and the presence of open fractures can both be viewed as markers of more serious injury. However, we were not able to quantify trauma energy levels, nor the impact of other complicating injuries.

The low rate of nonunion in our series resulted in poor statistical power to analyse risk factors. Future studies on this topic should ideally be prospective and would most easily be performed at centres with high rates of nonunion. For example, the use of stainless-steel or titanium could be randomized. Unfortunately, findings from such centres may not be generalizable to geriatric patients.

Our finding of a very low non-union rate in the elderly should not be interpreted as an argument that the biomechanical properties of the osteosynthesis are of minor importance. On the contrary, since the introduction of LLP in our institution, practically all cases are treated or supervised by orthopaedic surgeons subspecialised in trauma orthopaedics. During the early years of this series, fewer cases were operated as the procedure was still regarded as experimental. Today, LLP is the most common treatment in ambulating patients with distal femoral fractures, but we still believe they should be treated by surgeons with a high level of experience and biomechanical understanding. Surgical treatment can be complex in the face of pre-existing implants, severe comminution and gravely osteoporotic bone also in the low-energy trauma setting. However, despite the theoretical biomechanical advantages of titanium implants discussed above, it seems that stainless steel implants work well. In patients at low risk for non-union it seems difficult to find scientific evidence of the superiority of either material over the other.

In conclusion, we found a 4% rate of nonunion after LLP of distal femoral fractures. Lower age and the presence of an open fracture were associated with nonunion. We could not demonstrate any statistically significant difference in the rate of nonunion, or reoperations in general, between implants of stainless-steel and titanium, or an effect of other measured factors that affect the mechanical properties of the implant.

Contribution of authors

Study conception and design: DW. Data collection and analysis: DW and SA. Manuscript draft: SA. Critical revision of the article: DW and SA.

Conflict of interest

None.

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