



ORIGINAL PAPER

**[Translated article] Treatment of supracondylar femoral fractures by minimally invasive techniques vs. exposure of the fracture site: A retrospective cohort study**

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**KEYWORDS**

Distal femur fracture;  
Epidemiology;  
MIS;  
ORIF;  
Complications

**Abstract**

**Introduction:** Fractures of the distal femoral third are an important cause of morbidity and mortality, and their treatment is currently controversial.

**Objectives:** To compare the results between minimally invasive techniques versus exposure of the fracture site. Secondly, to evaluate the relationship between demographic factors, mechanism of injury and surgical delay with patient prognosis.

**Method:** Retrospective cohort study carried out between 2015 and 2021 in a tertiary hospital. Data collection was performed by reviewing medical histories, measuring demographic and hospital parameters and definitive treatment strategy. One year of follow-up was completed in all patients, assessing the occurrence of surgical complications and mortality. A stratified analysis of the variables of interest was performed among patients over 65 years of age.

**Results:** 128 fractures were recorded, with definitive osteosynthesis being performed in 117. Patients who underwent minimally invasive techniques required a shorter hospital stay (9 [7–12] vs. 12 [8.75–16] days) ( $p=0.007$ ), with no differences in mortality or complications during follow-up. In those over 65 years of age, opening the fracture site was associated with an increased risk of infection compared to minimally invasive techniques (33.3% vs. 2%) ( $p=0.507$ ). All the deceased were patients over 65 years of age (33.7% at one year). Surgical delay longer than 48 h increased mortality by 10% among those older than 65 years ( $p=0.3$ ). High-energy trauma had a higher proportion of pseudarthrosis (27.6% vs. 6.1%) ( $p=0.011$ ).

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**Conclusions:** Minimally invasive techniques decreased hospital stay but not complications or long-term mortality.

Level of evidence: IIb.

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## PALABRAS CLAVE

Fractura fémur distal;  
Epidemiología;  
MIS;  
RAFI;  
Complicaciones

## Tratamiento de fracturas supracondíleas de fémur mediante técnicas mínimamente invasivas vs. exposición del foco de fractura: un estudio de cohortes retrospectivas

### Resumen

**Introducción:** Las fracturas de tercio distal femoral son una causa importante de morbilidad, siendo su tratamiento actualmente controvertido.

**Objetivos:** Comparar los resultados entre las técnicas mínimamente invasivas frente a la exposición del foco de fractura. Secundariamente, evaluar la relación entre los factores demográficos, el mecanismo lesional y la demora quirúrgica con el pronóstico de los pacientes.

**Método:** Estudio tipo cohortes retrospectivas realizado entre 2015 y 2021 en un hospital de tercer nivel. La recogida de datos se realizó mediante la revisión de historias clínicas, midiendo los parámetros demográficos, hospitalarios y la estrategia de tratamiento definitivo. Se completó un año de seguimiento en todos los pacientes, evaluando la aparición de complicaciones quirúrgicas y mortalidad. Se realizó un análisis estratificado de las variables de interés entre pacientes mayores de 65 años.

**Resultados:** Se registraron 128 fracturas, realizándose la osteosíntesis definitiva en 117. Los pacientes intervenidos mediante técnicas mínimamente invasivas requirieron una menor estancia hospitalaria (9 [7-12] vs. 12 [8,75-16] días) ( $p=0,007$ ), sin diferencias en la mortalidad o complicaciones durante el seguimiento. En mayores de 65 años, la apertura del foco de fractura asoció un aumento del riesgo de infección frente a las técnicas mínimamente invasivas (33,3% vs. 2%) ( $p=0,507$ ). Todos los fallecidos fueron pacientes mayores de 65 años (33,7% al año). La demora quirúrgica superior a 48 horas aumentó la mortalidad un 10% entre los mayores de 65 años ( $p=0,3$ ). Los traumatismos de alta energía presentaron una mayor proporción de pseudoartrosis (27,6% vs. 6,1%) ( $p=0,011$ ).

**Conclusiones:** Las técnicas mínimamente invasivas disminuyeron la estancia hospitalaria pero no las complicaciones ni la mortalidad a largo plazo.

Nivel de evidencia: IIb.

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## Introduction

Fractures of the distal femoral third (those involving the supracondylar and intercondylar regions) make up approximately 3–7% of all femoral fractures, and account for less than 1% of all fractures.<sup>1,2</sup>

These fractures occur in the population in a bimodal distribution. The first peak of incidence occurs in young males with high-energy trauma, while the second peak is dominated by older women, with fractures caused by low-energy trauma.<sup>2,3</sup>

Surgery is the treatment of choice for most of these fractures; there are a wide variety of surgical strategies depending on joint extension, comminution, and the trace of the fracture, and the patient characteristics.<sup>4</sup>

In recent years there has been a tendency to treat this type of fracture with the least possible aggression to the soft tissues and early consolidation for prompt recovery in young patients, and to reduce short- and

medium-term complications in elderly patients. Therefore, minimally invasive techniques providing relative stability (intramedullary nailing and plates using MIPO techniques) has increased, but there is no consensus on the most appropriate surgical treatment for this type of fracture.

Therefore, knowing the different risk factors, and the suitability of each of the surgical options available to us helps us to individualise the treatment of each patient, to reduce the time necessary for functional recovery and the complications arising from these injuries and their treatment.

The primary objective of this study was to compare the progress of patients treated using minimally invasive techniques versus those whose fracture site needed to be opened during surgery. And to analyse these two treatment methods in patients over 65 years of age.

As secondary objectives, we sought to evaluate the different demographic factors, such as age or mechanism of injury, influencing the prognosis of this type of fracture, and

the potential influence of delaying definitive surgery on the prognosis of patients, especially in those over 65 years of age.

## Materials and methods

We conducted an analytical retrospective cohort study in patients with distal femoral fractures operated on between January 2015 and December 2021, in a tertiary level hospital attending a population of around 440,000 inhabitants, which is the referral centre for the province. The data for the present study were obtained from the database of fractures treated in the hospital over that period.

The data collection was based on an anonymous review of the clinical history of the patients, without providing the study with identifying data. Demographic parameters were collected, such as the patients' age and sex, and the mechanism of fracture (high or low energy), fracture classification (AO<sup>5</sup> classification for fractures of the distal femur and Gustilo and Anderson classification in the case of open fractures), time to surgery, and length of hospital stay. Parameters such as the treatment strategy used for each fracture, onset of acute surgical complications, and in-hospital mortality were collected during admission.

All patients were followed up for one year, after which the presence of long-term complications recorded in the clinical history during follow-up, and mortality over this period were evaluated.

All patients seen in the hospital where the study was conducted, over the period indicated above, who were diagnosed with acute fracture of the distal third of the femur were included in the present study.

Exclusion criteria were determined as follows:

- Peri-implant or periprosthetic fractures of devices implanted in the femoral middle and distal thirds.
- Patients under 14 years of age.
- Patients who did not complete the follow-up in the hospital where the present study was conducted, and incomplete follow-ups, or follow-ups of less than one year's duration.

A digital database was created with the parameters collected. A data management programme (IBM SPSS Statistics v.25) was used for the statistical analysis of the study. First, a descriptive study of the variables was performed, and the normality of the quantitative variables was determined using the Kolmogorov–Smirnov test. Nominal variables were described based on the relative frequencies of their respective categories. Qualitative variables were described with their median and interquartile range. Different bivariate analyses were performed, using the  $\chi^2$ , Mann–Whitney, Kruskal–Wallis, and Spearman statistical tests, according to the characteristics of the variables studied. Finally, those variables that showed statistically significant associations in the bivariate analysis were subjected to various multivariate tests to rule out confounding factors not controlled for during the study design, by performing binary logistic regression and linear regression of the variables.

We compared patients who underwent fracture fixation using minimally invasive techniques (using plates or

intramedullary nailing) with those who underwent fixation after opening the fracture site. The need to open the fracture site to achieve reduction was considered sufficient to include patients in the ORIF group, regardless of the type of implant used.

A stratified analysis was performed by age (patients over versus under 65 years of age) according to demographic variables, surgical technique used, and time to intervention.

The potential relationship between the delay in days to fracture intervention (in the first 48 h or later) and hospital stay, long-term complications, and mortality in the first year was tested.

The study was conducted in accordance with the ethical standards recognised by the Declaration of Helsinki and resolution 008430 of 1993, and was approved by the Ethics Committee for Biomedical Research of the province of Granada (CEI/CEIM Granada; code: 6hWMS821PFIRMAUegzkMz+S5FCmAr5). The patients participating in the study gave their informed consent.

## Results

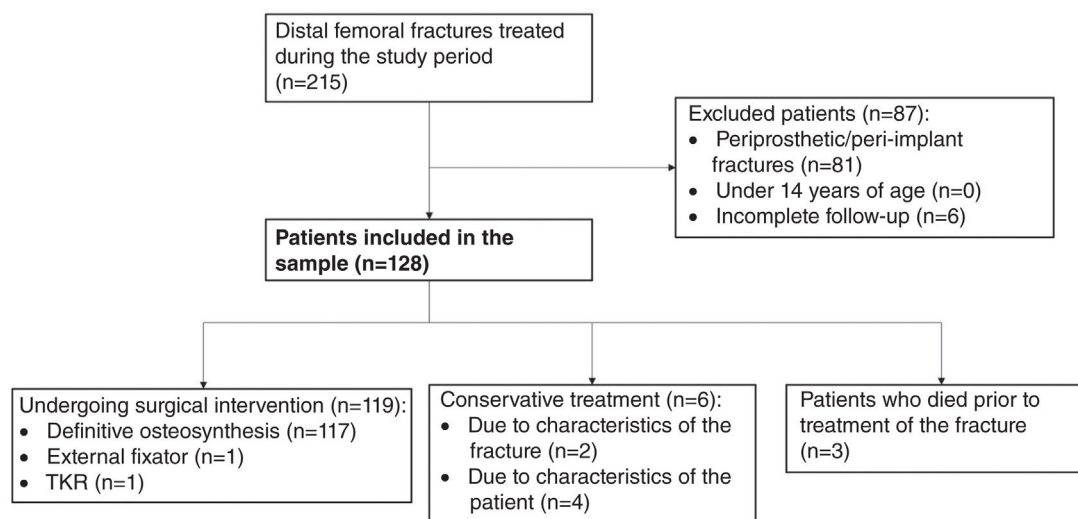
A total of 215 fractures of the distal femur were recorded during the period under study. Of these, 128 fractures met the inclusion criteria outlined above. A total of 119 fractures of the distal femur were operated, with 117 fractures undergoing definitive osteosynthesis (Fig. 1). One of the patients was treated temporarily by external fixation, but could not undergo definitive osteosynthesis due to his poor general condition during admission. This treatment was indicated in 2 of the 6 fractures treated conservatively, due to the characteristics of the fracture (minimal displacement, stable pattern), while in 4 of the cases, the patient's personal history contraindicated definitive surgery.

None of the quantitative variables showed a normal distribution during the descriptive statistical analysis of the sample.

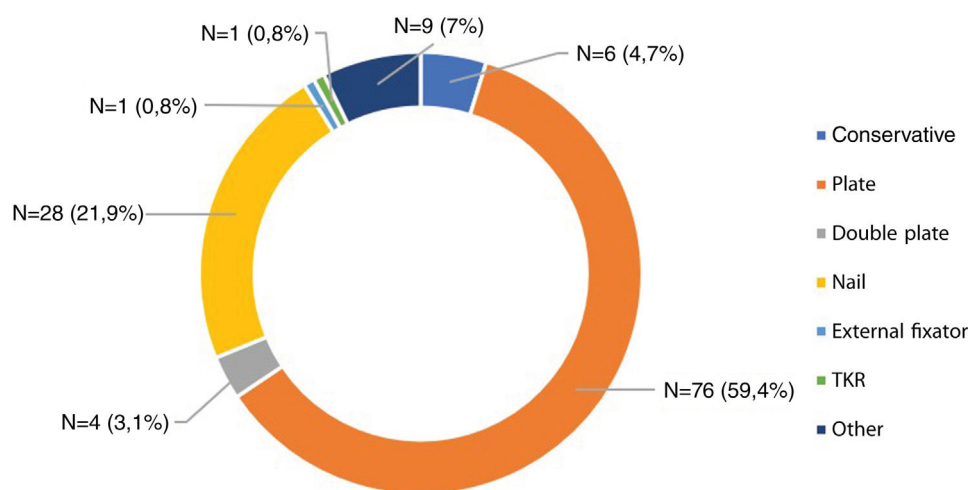
The median age of the patients included in the present study was 75 years, and the female sex predominated. Most of the fractures recorded were due to low-energy trauma. The median length of hospital stay was 10 days, with a median of 4 days until surgery if surgery was performed. A total of 92.9% of patients underwent surgery, with different plate-screw assemblies being the most commonly used (Fig. 2). Follow-up of 21 patients (16.4%) was not completed because they died within one year. Of the patients who completed follow-up, 27.3% suffered some kind of complication resulting from surgery.

No statistically significant age-dependent differences in surgical complications during follow-up were found. Sex ( $p = .001$ ) and low-energy trauma ( $p = .001$ ) were shown to be a risk factor for this type of fracture in the population over 65 years of age in the multivariate analysis performed. All the deaths recorded, both in-hospital and during follow-up, occurred in this age group (Table 1).

High-energy trauma showed a tendency to cause fractures in male patients ( $p = .015$ ) and in those under 65 years of age ( $p = .000$ ), and to cause open fractures in any age group compared to low-energy fractures ( $p = .046$ ), in the multivariate study. High-energy trauma was also associated with an increased proportion of complications at one-year



**Figure 1** Patient flow according to inclusion and exclusion criteria. TKR: total knee replacement.



**Figure 2** Surgical strategies used in our centre (patients treated by TKR or external fixation were not included in the statistical analysis comparing ORIF vs. MIS).

follow-up, especially pseudarthrosis and delayed fracture consolidation, although this did not reach statistical significance in the multivariate analysis (Table 2).

Minimally invasive techniques were associated with a shorter hospital stay, although these data were not consistent in the multivariate analysis ( $p = .372$ ). No differences were found between the two groups in terms of complications or mortality during follow-up (Table 3). Similarly, no significant differences were found between the two treatment options in terms of complications or mortality when analysing the subgroup of patients over 65 years of age (Table 4).

Days to fracture treatment correlated positively with days of hospital admission of patients, with a statistically significant relationship both in the overall sample ( $p = .000$ ) and in the subgroup of patients over 65 years of age ( $p = .001$ ) (Tables 5 and 6). The Spearman correlation index between days to intervention and hospital stay was positive with a value of .623 ( $p = .000$ ). Delaying intervention beyond 48 h

did not show an increase in complications during follow-up. Although mortality increased by 10% among the patients older than 65 years who underwent surgery after more than 48 h, this did not reach statistical significance ( $p = .3$ ) (Table 6).

## Discussion

The primary aim of the present study was to compare the evolution in terms of complications and mortality between the current different surgical approaches to treat fractures of the distal femoral third. Despite the size of our sample, we found no differences in terms of complications at one-year follow-up or mortality between opening the fracture site during surgery and the use of minimally invasive techniques.

Most of the fractures included in our study were treated surgically, we opted for conservative treatment only in

**Table 1** Comparative analysis >65 years and <65 years.

Parameter	Total (n = 128)	<65 years (n = 45)	>65 years (n = 83)	p
Sex, n (%)	Male 29 (22.7%) Female 99 (77.3%)	Male 26 (57.8%) Female 19 (42.2%)	Male 3 (3.6%) Female 80 (96.4%)	<b>.000</b>
Classification, n (%)	A 58 (45.3%) B 14 (10.9%) C 56 (43.8%)	A 20 (44.4%) B 5 (11.1%) C 20 (44.4%)	A 38 (45.8%) B 9 (10.8%) C 36 (43.4%)	<b>.99</b>
Energy, n (%)	High 29 (22.7%) Low 99 (77.3%)	High 22 (48.9%) Low 23 (51.1%)	High 7 (8.4%) Low 76 (91.6%)	<b>.000</b>
Open, n (%)	Closed 113 (88.3%) Open 15 (11.7%) GI 3 (2.3%) GII 5 (3.9%) GIII 7 (5.5%)	Closed 35 (77.8%) Open 10 (22.2%) GI 0 (0%) GII 3 (6.7%) GIII 7 (15.6%)	Closed 78 (94%) Open 5 (6%) GI 3 (3.6%) GII 2 (2.4%) GIII 0 (0%)	<b>.001</b>
Days to surgery, RI [25–75]	4 [2–6]	4 [2–8]	3 [2–5]	.239
Days of admission, RI [25–75]	10 [8–15]	11 [8–16]	9.5 [7–15]	.180
Complication during admission, n (%)	Reintervention 3 (2.3%)	Reintervention 1 (2.2%)	Reintervention 2 (2.4%)	.180
Death during admission, n (%)	7 (5.5%)	0 (0%)	7 (8.4%)	<b>.045</b>
Death in first year, n (%)	21 (16.4%)	0 (0%)	21 (25.3%)	<b>.000</b>
Complications in first year, n (%)	Pseudoarthrosis 14 (10.9%) Infection 4 (3.1%) Reintervention 2 (1.6%) Dysmetria 6 (4.7%) ROM 5 (3.9%) Amputation 3 (2.3%) Nerve damage 1 (.8%) Total 35 (27.3%)	Pseudoarthrosis 7 (15.6%) Infection 3 (6.7%) Reintervention 0 (0%) Dysmetria 3 (6.7%) ROM 3 (6.7%) Amputation 2 (4.4%) Nerve damage 1 (2.2%) Total 19 (42.2%)	Pseudoarthrosis 7 (8.4%) Infection 1 (1.2%) Reintervention 2 (2.4%) Dysmetria 3 (3.6%) ROM 2 (2.4%) Amputation 1 (1.2%) Nerve damage 0 (0%) Total 16 (19.3%)	.659 .211 .200 .782 .476 .434 .262 .128
Multivariate				
Variables	RR	CI (95%)	p	
Sex	1.903	(1.313–2.756)	<b>.001</b>	
Energy	.154	(.051–.466)	<b>.001</b>	
Open fracture	.648	(.336–1.250)	.196	
Days of admission	1.1013	(.977–1.050)	.479	
Complications during admission	1.195	(.525–2.720)	.671	
Complications in the first year	.838	(.659–1.065)	.149	

Results that achieved statistical significance are marked in bold.

patients in whom surgical intervention was not advisable, due to their baseline condition, or limited fracture displacement.

On this point, the current literature maintains that surgery is the treatment of choice for this type of fracture, with the aim of achieving rapid mobilisation of the affected limb, allowing the limb to recover its functionality<sup>6,7</sup>; and there is currently no clear recommendation as to which type of surgical technique is the most appropriate.<sup>4,8</sup>

Minimally invasive techniques, more respectful of soft tissues,<sup>9</sup> have gained ground in the most recent literature, especially focused on elderly patients, in whom the priority objective must be early mobilisation and weight-bearing, restoring the axis of the limb, and relegating to second place the anatomical reduction of the fracture, even at the joint level.<sup>10,11</sup>

Of the surgical options deployed in our study (Fig. 2), both anatomical and locked plates were selected for implantation in most of the patients (59.4%) (Fig. 3), followed by intramedullary nailing in 21.9% of cases.

Retrograde nailing is especially indicated in the literature in extra-articular and partially articular fractures.<sup>12,13</sup> Relative stability of the fracture synthesis is achieved with this system, which does not provide adequate control of the varus/valgus of the fracture site, which means opening the fracture site in a significant number of cases to improve fracture reduction (Fig. 4).

Condylar plates are now widely used and allow minimally invasive treatment through relative stability. The MIPO concept involves indirect reduction of the fracture by inserting the plate below the musculature and above the periosteum. The reduced dissection of soft tissue at the



**Table 2** Comparative analysis of the mechanism of injury.

Parameter	Total (n = 128)	High energy (n = 29)	Low energy (n = 99)	p
Sex, n (%)	Male 29 (22.7%) Female 99 (77.3%)	Male 18 (62.1%) Female 11 (37.9%)	Male 11 (11.1%) Female 88 (88.9%)	<b>.000</b>
Age, IQR [25–75]	75 [56–86]	49 [39–62.5]	79 [67–88]	<b>.000</b>
>65 years, n (%)	>65 years 83 (64.8%) <65 years 45 (35.2%)	>65 years 7 (24.1%) <65 years 22 (75.9%)	>65 years 76 (76.8%) <65 years 23 (23.2%)	<b>.000</b>
Classification, n (%)	A 58 (45.3%) B 14 (10.9%) C 56 (43.8%)	A 10 (34.5%) B 2 (6.9%) C 17 (58.6%)	A 48 (48.5%) B 12 (12.1%) C 39 (39.4%)	.097
Open, n (%)	Closed 113 (88.3%) Open 15 (11.7%) GI 3 (2.3%) GII 5 (3.9%) GIII 7 (5.5%)	Closed 19 (65.5%) Open 10 (34.5%) GI 0 (0%) GII 3 (10.3%) GIII 7 (24.1%)	Closed 94 (94.9%) Open 5 (5.1%) GI 3 (3%) GII 2 (2%) GIII 0 (0%)	<b>.000</b>
Days to surgery, IQR [25–75]	4 [2–6]	4 [0–9]	4 [2–5]	.649
Days of admission, IQR [25–75]	10 [8–15]	11 [8–17]	10 [8–15]	.466
Complications during admission, n (%)	Reintervention 3 (2.3%)	Reintervention 1 (3.4%)	Reintervention 6 (6.1%)	.367
Death during admission, n (%)	7 (5.5%)	0 (0%)	7 (7.1%)	.141
Death first year, n (%)	21 (16.4%)	0 (0%)	21 (21.2%)	<b>.005</b>
Complications first year, n (%)	Pseudoarthrosis 14 (10.9%) Infection 4 (3.1%) Reintervention 2 (1.6%) Dysmetria 6 (4.7%) ROM 5 (3.9%) Amputation 3 (2.3%) Nerve damage 1 (.8%) Total 35 (27.3%)	Pseudoarthrosis 8 (27.6%) Infection 2 (6.9%) Reintervention 0 (0%) Dysmetria 3 (10.3%) ROM 3 (10.3%) Amputation 0 (0%) Nerve damage 0 (0%) Total 16 (55.2%)	Pseudoarthrosis 6 (6.1%) Infection 2 (2%) Reintervention 2 (2%) Dysmetria 3 (3%) ROM 2 (2%) Amputation 3 (3%) Nerve damage 1 (1%) Total 19 (19.2%)	<b>.011</b> .337 .365 .235 .113 .264 .524 <b>.004</b>
Multivariate				
Variables	RR	CI (95%)	p	
Sex	2.502	(1.196–5.235)	<b>.015</b>	
Age	.951	(.933–.970)	<b>.000</b>	
Classification	1.292	(.752–2.221)	.353	
Open fracture	1.422	(1.015–5.779)	<b>.046</b>	
Complications first year	.5	(.171–1.463)	.206	
Pseudoarthrosis first year	2.667	(.591–12.042)	.202	

Results that achieved statistical significance are marked in bold.

fracture site appears to promote fracture consolidation.<sup>14,15</sup> This technique is especially indicated when there is significant metaphyseal involvement, in osteoporotic bone and in periprosthetic fractures.

In our study, the patients treated using minimally invasive techniques had a significantly reduced hospital stay (from 12 to 9 days compared to patients in whom the fracture site was opened), which is similar to the literature consulted.<sup>16</sup> In the patients over the age of 65 years in our study, the difference was reduced to only one day, probably in relation to the patients' baseline comorbidities and their lower functional

reserve to cope with major surgery, regardless of the surgical technique deployed.

We found no differences in terms of complications in the first year of follow-up between the two groups in general terms, in either infection or, more specifically, delayed healing. However, in patients over 65 years of age, opening the fracture site was associated with a higher rate of infection at one year follow-up (33% versus 2% for the minimally invasive techniques). Although the small sample size of this subgroup means we should view this result with caution because it did not reach statistical significance, we consider it to be

**Table 3** Comparative analysis minimally invasive surgery (MIS) vs. ORIF.

Parameter	Total (n = 117)	MIS (n = 67)	ORIF (n = 50)	p
Days to surgery, IQR [25–75]	4 [2–6]	3 [1–4]	4 [2–8]	<b>.017</b>
Days of admission, RI [25–75]	10 [8–15]	9 [7–12]	12 [8.75–16]	<b>.007</b>
Complications during admission, n (%)	Reintervention 3 (2.6%)	Reintervention 2 (3%)	Reintervention 1 (2%)	.397
Deaths during admission, n (%)	5 (4.3%)	2 (3%)	3 (6%)	.425
Deaths first year, n (%)	18 (15.4%)	13 (19.4%)	5 (10%)	.183
Complications first year, n (%)	Pseudoarthrosis 14 (12%)	Pseudoarthrosis 7 (10.4%)	Pseudoarthrosis 7 (14%)	.637
	Infection 4 (3.4%)	Infection 2 (3%)	Infection 2 (4%)	.812
	Reintervention 2 (1.7%)	Reintervention 2 (3%)	Reintervention 8 (16%)	.203
	Dysmetria 6 (5.1%)	Dysmetria 4 (6%)	Dysmetria 2 (4%)	.579
	ROM 4 (3.4%)	ROM 1 (1.5%)	ROM 3 (6%)	.205
	Amputation 2 (1.7%)	Amputation 1 (1.5%)	Amputation 1 (2%)	.868
	Nerve damage 1 (.9%)	Nerve damage 0 (0%)	Nerve damage 1 (2%)	.259
	Total 33 (28.2%)	Total 17 (25.4%)	Total 16 (32%)	<b>.541</b>
Multivariate				
Variables	RR	IC (95%)	p	
Days to surgery	1.099	(.952–1.268)	.198	
Days of admission	.974	(.920–1.032)	.372	
Deaths first year	.365	(.118–1.132)	.081	

Results that achieved statistical significance are marked in bold.

**Table 4** Comparative analysis minimally invasive surgery (MIS) vs. ORIF in patients over 65 years of age.

Parameter	>65 years (n = 83)	MIS (n = 51)	ORIF (n = 24)	p
Days to surgery, IQR [25–75]	3 [2–5]	3 [1.5–5]	4 [2–5]	.651
Days of admission, IQR [25–75]	9.5 [7–15]	10 [7–13]	9 [8–15]	.699
Complications during admission, n (%)	Reintervention 2 (2.4%)	Reintervention 2 (3.9%)	Reintervention 0 (0%)	.11
Deaths during admission, n (%)	7 (8.4%)	2 (3.9%)	3 (12.5%)	.165
Deaths first year, n (%)	21 (25.3%)	13 (25.5%)	5 (20.8%)	.811
Complications first year, n (%)	Pseudoarthrosis 7 (8.4%)	Pseudoarthrosis 4 (7.8%)	Pseudoarthrosis 3 (12.5%)	.433
	Infection 1 (1.2%)	Infection 1 (2%)	Infection 8 (33.3%)	.507
	Reintervention 2 (2.4%)	Reintervention 2 (3.9%)	Reintervention 0 (0%)	.343
	Dysmetria 3 (3.6%)	Dysmetria 2 3.9(%)	Dysmetria 1 (4.2%)	.903
	ROM 2 (2.4%)	ROM 0 (0%)	ROM 1 (4.2%)	.125
	Amputation 1 (1.2%)	Amputation 0 (0%)	Amputation 0 (0%)	–
	Nerve damage 0 (0%)	Nerve damage 0 (0%)	Nerve damage 0 (0%)	–
	Total 16 (19.3%)	Total 9 (17.6%)	Total 5 (20.8%)	.600

a result worth highlighting, especially on the basis of previous literature. A recent study<sup>17</sup> relates different risk factors such as diabetes mellitus, obesity, or the presence of an open fracture as determinants for the development of surgical infection in patients in whom the fracture site was opened to achieve adequate reduction, reflecting an overall infection rate of 4%, significantly lower than the results of our study.

Along the same lines, a systematic review published by Zlowodzki et al.,<sup>18</sup> described a reduction in the proportion of infections when minimally invasive techniques were used. However, in the same review, the authors found an increase in material failure and the need for revision surgery in these techniques, we did not have these results in our study. It is important to note at this point that the choice of implant to

be used may be influenced by the fracture pattern. Therefore, implants associated with minimally invasive techniques (such as intramedullary nailing) may not be suitable for the treatment of more complex fractures which have a worse overall or functional prognosis, which is a potential source of bias both in the present study and in the previously published literature.

The risk factors for the failure of minimally invasive implants described in the literature include obesity, open fractures, infection of the surgical site, or the use of stainless steel implants<sup>19</sup> (Fig. 5).

The mortality of patients treated by minimally invasive techniques was reduced by half compared to those in whom the fracture site was opened in the analysis of the overall group of patients (19.4% vs. 10%). The previous literature

**Table 5** Analysis of time to surgery.

Parameter	Total (n = 117)	<48 h to surgery (n = 40)	>48 h to surgery (n = 77)	p
Days of admission, IQR [25–75]	10 [8–15]	7 [6–9.5]	12 [9–17]	<b>.000</b>
Complications during admission, n (%)	Reintervention 3 (2.6%)	Reintervention 1 (2.4%)	Reintervention 2 (2.6%)	.915
Deaths during admission, n (%)	5 (4.3%)	1 (2.4%)	4 (5.2%)	.479
Deaths first year, n (%)	18 (15.4%)	5 (12.2%)	13 (16.9%)	.461
Complications first year, n (%)	Pseudoarthrosis 14 (12%)	Pseudoarthrosis 7 (17.1%)	Pseudoarthrosis 7 (9.1%)	.255
	Infection 4 (3.4%)	Infection 1 (2.4%)	Infection 3 (3.9%)	.627
	Reintervention 2 (1.7%)	Reintervention 0 (0%)	Reintervention 2 (2.6%)	.279
	Dysmetria 6 (5.1%)	Dysmetria 1 (2.4%)	Dysmetria 5 (6.5%)	.298
	ROM 4 (3.4%)	ROM 1 (2.4%)	ROM 3 (5.2%)	.432
	Amputation 2 (1.7%)	Amputation 0 (0%)	Amputation 2 (2.6%)	.279
	Nerve damage 1 (.9%)	Nerve damage 1 (2.4%)	Nerve damage 0 (0%)	.184
	Total 33 (28.2%)	Total 11 (26.8%)	Total 22 (28.6%)	<b>.536</b>
Multivariate				
Variables	RR	CI (95%)	p	
Days of admission	1.323	(1.16–1.5)	<b>.000</b>	

Results that achieved statistical significance are marked in bold.

**Table 6** Analysis of days until surgery in patients over 65 years of age.

Parameter	>65 years (n = 83)	<48 h to surgery (n = 28)	>48 h to surgery (n = 48)	p
Days of admission, IQR [25–75]	9 [7–15]	7 [6–8]	11.5 [9–17]	<b>.000</b>
Complications during admission, n (%)	Reintervention 2 (2.4%)	Reintervention 1 (3.6%)	Reintervention 1 (2.1%)	.822
Deaths during admission, n (%)	7 (8.4%)	1 (3.6%)	4 (8.3%)	.419
Deaths first year, n (%)	21 (25.3%)	5 (17.9%)	13 (27.1%)	.3
Complications first year, n (%)	Pseudoarthrosis 7 (8.4%)	Pseudoarthrosis 4 (14.3%)	Pseudoarthrosis 3 (6.3%)	.344
	Infection 1 (1.2%)	Infection 0 (0%)	Infection 1 (2.1%)	.403
	Reintervention 2 (2.4%)	Reintervention 0 (0%)	Reintervention 2 (4.2%)	.232
	Dysmetria 3 (3.6%)	Dysmetria 1 (3.6%)	Dysmetria 2 (4.2%)	.788
	ROM 2 (2.4%)	ROM 0 (0%)	ROM 2 (4.2%)	.232
	Amputation 1 (1.2%)	Amputation 0 (0%)	Amputation 0 (0%)	–
	Nerve damage 0 (0%)	Nerve damage 0 (0%)	Nerve damage 0 (0%)	–
	Total 16 (19.3%)	Total 5 (17.9%)	Total 10 (20.8%)	<b>.492</b>
Multivariate				
Variables	RR	CI (95%)	p	
Days of admission	1.317	(1.116–1.555)	<b>.001</b>	

Results that achieved statistical significance are marked in bold.

consulted found no differences in terms of mortality during patient follow-up depending on the type of osteosynthesis or implant used.<sup>20</sup>

It should be noted that, in our study, all deaths occurred in the patients over 65 years of age, adding 8.4% in-hospital mortality and 25.3% mortality at the first year of follow-up. This accumulated mortality at one year is similar to that described in similar studies in which it is around 30%, age being an independent predictor of mortality in this type of fracture.<sup>7,20</sup> Various studies have highlighted the similarities between supracondylar fractures and hip fractures in elderly patients, with similar mortality in both and a benefit in early surgical treatment in the first 48 h.<sup>21–25</sup>

When comparing the mortality of both techniques in this subgroup, we found no differences between patients treated by minimally invasive techniques and ORIF (25.5% vs. 20.8%), it was even slightly higher in those patients undergoing minimally invasive techniques. This may be explained by the high number of elderly patients treated by minimally invasive techniques in our sample, age being a potential confounding factor in the true mortality of the surgical options.

The demographic characteristics of the patients under study showed a characteristic bimodal distribution already described in previous literature<sup>2,3</sup> (Table 1). On the one hand, most were patients over 65 years of age, predominantly women, with closed supra- and intercondylar

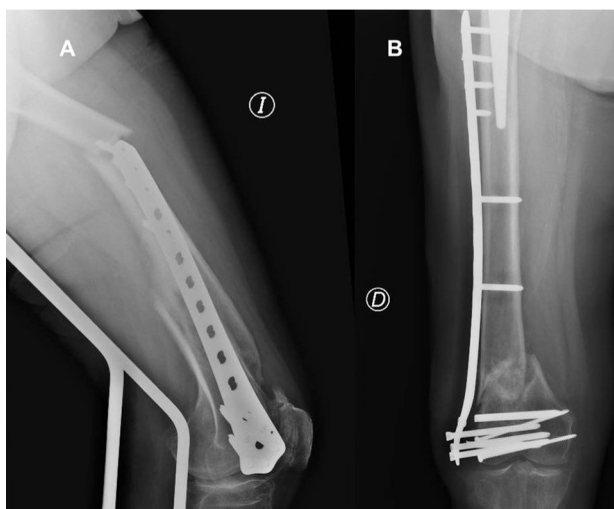




**Figure 3** Clinical cases treated with plates: compression plate (A), bridge plating (B), bridge plating combined with compression screw for Hoffa's fracture (C), and double anti-slip plate systems (D and E).



**Figure 4** Clinical case: supracondylar femoral fracture type A (AO/OTA) treated by retrograde intramedullary nailing.

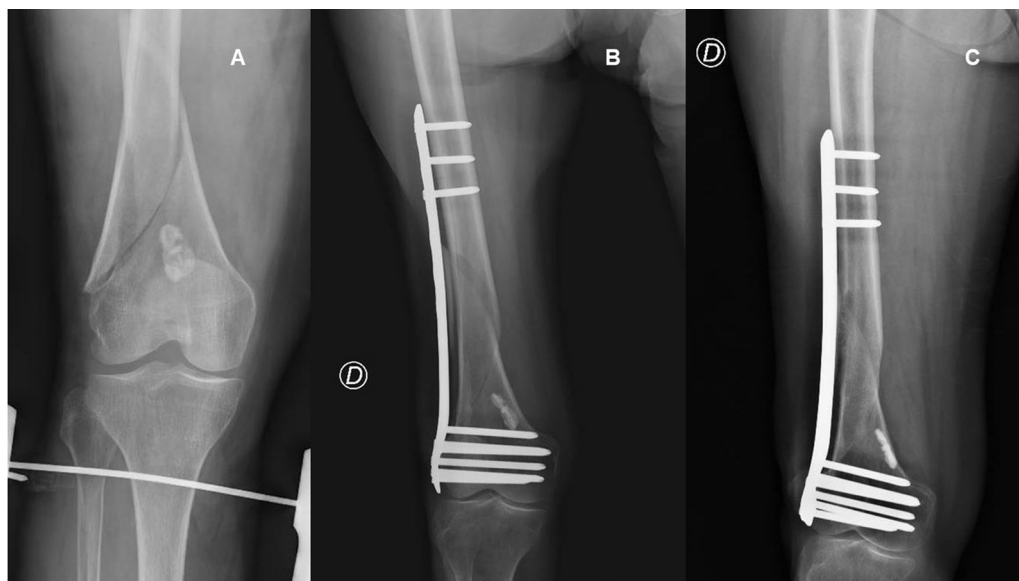


**Figure 5** Examples of material failures: peri-implant fracture (A). Failure of locking plate screws (B).

fractures of the distal femur following low-energy trauma, associated with a personal history of osteoporosis.<sup>26</sup> On the other hand were young patients suffering high energy trauma, which is associated with a greater number of open fractures, and more complex fracture patterns, and there was a predominance of males within this group.

We found a higher rate of complications at one year follow-up in the group of patients under 65 years of age, double the complications recorded in the older group, especially in terms of the development of delayed fracture healing and infectious fracture complications, which is probably related to the greater soft tissue damage and higher rate of open fractures in this group of patients.

High-energy mechanisms of injury were associated with a high percentage of open fractures with significant soft-tissue damage, and greater severity on the Gustilo scale. It seems logical to think that high-energy trauma involves greater tissue and associated soft tissue injury, and greater force absorption by bone tissue, resulting in greater fracture complexity. Previous studies have found similar results



**Figure 6** Case of delayed union. Image of initial fracture (A), early postoperative (B) and at 6 months follow-up (C).

with increased fracture pattern complexity and a higher rate of open fractures in fractures secondary to high-energy trauma.<sup>26,27</sup>

Fractures secondary to high-energy trauma had more complications during the first year of follow-up, especially delayed consolidation (Fig. 6). Previous studies have related the presenting with an open distal femoral fracture with a delay in its consolidation,<sup>27,28</sup> which may explain the increase in delayed consolidation in the group of patients with high-energy fractures. There being no deaths during follow-up in the group of patients who suffered high-energy trauma could be partially due to chance, as it is unlikely that there would be no deaths among polytrauma patients with distal femoral fractures.

Surgical delay of this type of fracture beyond 48 hours was associated in our sample with an increased hospital stay. This result is in line with previously published literature, such as the study by Yamamoto et al.,<sup>29</sup> in which a delay in surgery to these fractures of more than 48 h was associated with an increase in hospital stay and total hospitalisation costs.

While not statistically significant, delayed intervention beyond 48 h among those aged 65 years and older resulted in increased mortality during admission, as well as a 10% increase in mortality at 1-year follow-up. We did not find a significant increase in other complications during patient follow-up. Previously published studies reinforce the importance of surgery in the first 48 h, finding an increase in mortality in patients undergoing surgery late at one month, six months, and one year of follow-up, with mortality figures close to those described for hip fractures.<sup>22,23</sup>

The main limitation of our study is that it is retrospective, although the large sample size, and the similarity of the

characteristics of our sample to previously published studies on the same pathology, increases its power. We cannot ignore the disparity in the surgical criteria of the different surgeons involved in the treatment of the patients in this study. The choice of different implants or techniques for similar fractures is a factor that is difficult to control within the sample. Similarly, the loss to follow-up of a high percentage of patients due to their death limits the power of the analysis of potential long-term complications. However, this loss of patients is similar to that of the literature consulted, being inherent to the progression of the condition itself. In any case, future studies with a higher level of evidence would be interesting to consolidate the conclusions reached in this study.

## Conclusions

Minimally invasive techniques reduce hospital stay but not complications or long-term mortality. In people over 65 years of age, opening the fracture site was associated with an increased risk of infection during follow-up. All deaths in the study occurred in those over 65 years of age, with no differences between the different surgical techniques. A delay of more than 48 hours to surgery in those over 65 years of age increased mortality rates in hospital and during the first year of follow-up. High-energy trauma fractures had a higher proportion of complications during follow-up, especially delayed healing.

## Level of evidence

Level of evidence IIb.

## Ethical considerations

The present study was approved by the clinical research ethics committee (CEIC) of the hospital where it was conducted.

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## Conflict of interests

The authors have no conflict of interests to declare.

## References

- Link BC, Babst R. Current concepts in fractures of the distal femur. *Acta Chir Orthop Traumatol Cech.* 2012;79:11–20.
- Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. *Injury.* 2006;37:691–7, <http://dx.doi.org/10.1016/j.injury.2006.04.130>.
- Martinet O, Cordey J, Harder Y, Maier A, Buhler M, Barraud GE. The epidemiology of fractures of the distal femur. *Injury.* 2000;31:62–3, [http://dx.doi.org/10.1016/S0020-1383\(00\)80034-0](http://dx.doi.org/10.1016/S0020-1383(00)80034-0).
- Bertrand ML, Andres-Cano P, Pascual-Lopez FJ. Periarticular fractures of the knee in polytrauma patients. *Open Orthop J.* 2015;9:332–46, <http://dx.doi.org/10.2174/1874325001509010332>.
- Kellam JF, Meinberg EG, Agel J, Karam M, Roberts C, Wilber J, et al. Fracture and dislocation classification compendium-2018 international comprehensive classification of fractures and dislocations committee. *J Orthop Trauma.* 2018;32:S1–170.
- Gwathmey FW, Jones-Quaidoo SM, Kahler D, Hurwitz S, Cui Q. Distal femoral fractures: current concepts. *J Am Acad Orthop Surg.* 2010;18:597–607, <http://dx.doi.org/10.5435/00124635-201010000-00003>.
- Canton G, Giraldo G, Dussi M, Ratti C, Murena L. Osteoporotic distal femur fractures in the elderly: peculiarities and treatment strategies. *Acta Biomed.* 2019;90 Suppl. 12:25–32, <http://dx.doi.org/10.23750/abm.v90i12-S.8958>.
- Griffin XL, Parsons N, Zbaeda MM, McArthur J. Interventions for treating fractures of the distal femur in adults. *Cochrane Database Syst Rev.* 2015;CD010606, <http://dx.doi.org/10.1002/14651858.CD010606.pub2>.
- Kumar R, Mohapatra SS, Joshi N, Goyal SK, Kumar K, Gora R. Primary ilizarov external fixation in open grade III type C distal femur fractures: Our experience. *J Clin Orthop Trauma.* 2019;10:928–33, <http://dx.doi.org/10.1016/j.jcot.2019.01.026>.
- Nester M, Borrelli J. Distal femur fractures management and evolution in the last century. *Int Orthop.* 2023;47:2125–35, <http://dx.doi.org/10.1007/s00264-023-05782-1>.
- Krettek C, Müller M, Miclau T. Evolution of minimally invasive plate osteosynthesis (MIPO) in the femur. *Injury.* 2001;32 Suppl. 3:SC14–23, [http://dx.doi.org/10.1016/S0020-1383\(01\)00180-2](http://dx.doi.org/10.1016/S0020-1383(01)00180-2).
- Gao K, Gao W, Huang J, Li H, Li F, Tao J, et al. Retrograde nailing versus locked plating of extra-articular distal femoral fractures: comparison of 36 cases. *Med Princ Pract.* 2013;22:161–6, <http://dx.doi.org/10.1159/000342664>.
- Gill SPS, Mittal A, Raj M, Singh P, Singh J, Kumar S. Extra articular supracondylar femur fractures managed with locked distal femoral plate or supracondylar nailing: a comparative outcome study. *J Clin Diagn Res.* 2017;11, <http://dx.doi.org/10.7860/JCDR/2017/25062.9936>. UNSP RC19-RC23.
- Wong MK, Leung F, Chow SP. Treatment of distal femoral fractures in the elderly using a less-invasive plating technique. *Int Orthop.* 2005;29:117–20, <http://dx.doi.org/10.1007/s00264-004-0609-3>.
- Hoffmann MF, Jones CB, Sietsema DL, Tornetta P, Koenig SJ. Clinical outcomes of locked plating of distal femoral fractures in a retrospective cohort. *J Orthop Surg.* 2013;8:43, <http://dx.doi.org/10.1186/1749-799X-8-43>.
- Nayak RM, Koichade MR, Umre AN, Ingle MV. Minimally invasive plate osteosynthesis using a locking compression plate for distal femoral fractures. *J Orthop Surg Hong Kong.* 2011;19:185–90.
- Lu K, Zhang J, Cheng J, Lui H, Yang C, Yin C, et al. Incidence and risk factors for surgical site infection after open reduction and internal fixation of intra-articular fractures of distal femur: a multicentre study. *Int Wound J.* 2019;16:473–8, <http://dx.doi.org/10.1111/iwj.13056>.
- Zlowodzki M, Bhandari M, Marek DJ, Cole PA, Kregor PJ. Operative treatment of acute distal femur fractures: systematic review of 2 comparative studies and 45 case series (1989–2005). *J Orthop Trauma.* 2006;20:366–71, <http://dx.doi.org/10.1097/00005131-200605000-00013>.
- Rodriguez EK, Boulton C, Weaver MJ, Herder LM, Morgan JH, Chacko AT, et al. Predictive factors of distal femoral fracture nonunion after lateral locked plating: a retrospective multicenter case-control study of 283 fractures. *Injury.* 2014;45:554–9, <http://dx.doi.org/10.1016/j.injury.2013.10.042>.
- García Guirao AJ, Andrés Cano P, Moreno Domínguez R, Giráldez Sánchez M, Cano Luis P. Análisis de la mortalidad tras el tratamiento quirúrgico de las fracturas periprotésicas de fémur distal. *Rev Esp Cir Ortop Traumatol.* 2020;64:92–8, <http://dx.doi.org/10.1016/j.recot.2019.11.002>.
- Jennison T, Divekar M. Geriatric distal femoral fractures: a retrospective study of 30 day mortality. *Injury.* 2019;50:444–7, <http://dx.doi.org/10.1016/j.injury.2018.10.035>.
- Streubel PN, Ricci WM, Wong A, Gardner MJ. Mortality after distal femur fractures in elderly patients. *Clin Orthop Relat Res.* 2011;469:1188, <http://dx.doi.org/10.1007/s11999-010-1530-2>.
- Myers P, Laboe P, Johnson KJ, Fredericks PD, Crichlow RJ, Maar DC, et al. Patient mortality in geriatric distal femur fractures. *J Orthop Trauma.* 2018;32:111–5, <http://dx.doi.org/10.1097/BOT.0000000000001078>.
- Rodrigo Merino-Rueda L, Rubio-Saez I, Mills S, Carlos Rubio-Suarez J. Mortality after distal femur fractures in the elderly. *Injury.* 2021;52:S71–5, <http://dx.doi.org/10.1016/j.injury.2021.03.066>.
- Smith JRA, Halliday R, Aquilina AL, Morrison RJM, Yip GCK, McArthur J, et al. Distal femoral fractures. The need to review the standard of care. *Injury.* 2015;46:1084–8, <http://dx.doi.org/10.1016/j.injury.2015.02.016>.
- Elsoe R, Ceccotti AA, Larsen P. Population-based epidemiology and incidence of distal femur fractures. *Int Orthop.* 2018;42:191–6, <http://dx.doi.org/10.1007/s00264-017-3665-1>.
- Roy D, Ramski D, Malige A, Beck M, Jeffers K, Brogle P. Injury patterns and outcomes associated with fractures of the native distal femur in adults. *Eur J Trauma Emerg Surg.* 2021;47:1123–8, <http://dx.doi.org/10.1007/s00068-019-01287-y>.

28. Cone R, Roszman A, Conway Y, Cichos K, McGwin G, Spitler CA. Risk factors for nonunion of distal femur fractures. *J Orthop Trauma*. 2023;37:175–80, <http://dx.doi.org/10.1097/BOT.0000000000002553>.
29. Yamamoto N, Ohbe H, Tomita Y, Yorifuji T, Nakajima M, Sasabuchi Y, et al. Associations between early surgery and postoperative outcomes in elderly patients with distal femur fracture: a retrospective cohort study. *J Clin Med*. 2021;10:5800, <http://dx.doi.org/10.3390/jcm10245800>.