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Femoral Shaft Fractures Treated by Intramedullary Interlocked Nailing

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Purpose. To evaluate the results of femoral shaft fractures treated by closed interlocked nailing, throughout an analysis of clinical and radiological findings.
Materials and methods. Retrospective study of 150 consecutive patients (156 femoral fractures) treated by closed interlocked nailing, over a period of 15 years (1987-2002). Fractures were classified and studied, analyzing the timing and type of surgical intervention, as well as intraoperative and postoperative complications. We performed a clinical evaluation concerning pain and function, as well as a radiological multiobserver analysis regarding the time of healing, rotational malalignment and malunion.
Results. Most fractures occurred after motor vehicle accidents (86.6%), with a predominance of males (71%) and with a mean age of 26.9 years (range 14-85); 17% were open fractures. The average follow-up was 35.7 months (range 18-174). 67% of the cases presented with associated fractures. The most frequent complication was pain in the area where the nail was introduced (5.8%). Radiological consolidation was achieved in all cases. In 12 cases (7.7%) an additional surgical procedure was necessary for final consolidation.
Conclusions. We can conclude that closed intramedullary nailing of femoral fractures permits excellent fracture healing, early patient recovery and few complications.

Key words: *intramedullary nailing, femoral fractures, multiple trauma.*

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Tratamiento de las fracturas diafisarias de fémur mediante clavo intramedular cerrojado

Objetivo. Analizar el tratamiento de las fracturas diafisarias de fémur mediante enclavado intramedular encerrojado y los resultados obtenidos clínica y radiológicamente.
Material y método. Estudio retrospectivo de fracturas diafisarias de fémur tratadas mediante enclavado intramedular encerrojado: en 150 pacientes consecutivos (156 fracturas), intervenidos en el Hospital Universitario de Tarragona Joan XXIII durante un período de 15 años (1987-2002). Las fracturas han sido clasificadas y se han analizado el momento y el tipo de intervención quirúrgica y las complicaciones intra y postoperatorias. El tiempo medio de seguimiento fue de 35,7 meses (18-174). La valoración clínica final incluye el dolor y la función junto a un análisis radiológico multiobservador del tiempo de consolidación, posible consolidación en mala posición y dismetría.
Resultados. La mayoría de las fracturas se produjeron en accidentes de tráfico (86,6%), afectando con mayor frecuencia a varones (71%) y a jóvenes (edad media de 26,9 años [14-85]). Un 17% de las fracturas fueron abiertas y en el 67% de los casos presentaron lesiones asociadas. La complicación postoperatoria más frecuente fue el dolor en la zona de introducción del clavo (5,8%). En 12 casos (7,7%) fue necesaria la reintervención quirúrgica para obtener la consolidación definitiva, pero finalmente se obtuvo la consolidación clínica y radiológica en todos los pacientes.
Conclusiones. La intervención quirúrgica precoz, en pacientes estables, ha disminuido el índice de complicaciones inmediatas en nuestra serie. Con el tratamiento de las fracturas de fémur mediante enclavado intramedular encerrojado hemos obtenido buenos resultados clínicos y radiológicos con un reducido índice de complicaciones.

Palabras clave: *enclavado intramedular, fracturas de fémur, politraumatizado.*

Femoral shaft fractures, usually caused by high-energy trauma, are a primary cause of the morbidity and mortality in our environment. The treatment of choice is interlocked intramedullary nailing further to physeal closure. An interlocked nailing system enables rotational control and prevents shortening, both of which are common complications when non-interlocked nailing is used. This is a retrospective analysis of our experience of the treatment of femoral shaft fractures by interlocked intramedullary nailing.

MATERIALS AND METHODS

Retrospective analysis of 178 consecutive patients treated for femoral shaft fracture by interlocked intramedullary nailing, from 1987 to 2002. The inclusion criterion for femoral shaft fractures involved those fractures situated in the segment extending between a point 2.5cm distal from the lesser trochanter and a point 8 cm proximal to the joint line. The following types of fracture were excluded: bifocal fractures (5 cases), pathological fractures (9 cases), periprosthetic fractures (9 cases), as well as cases of discontinued follow-ups. The latter were due to the patients' transfer to other health centers.

The series that was finally analyzed consisted of 150 patients (156 fractures) that had undergone treatment with an average follow-up of 35.7 months (18-174). 107 of the patients were male (71%) and 43 were female (29%). The mean age at the time of fracture was 26.9 years (range 14-85). In six of these patients (4%) the fracture was bilateral.

We classified the fractures according to their location (proximal third, middle third or distal third). We analyzed the degree of comminution following the classification of Winquist and Hansen[1]. Open fractures were classified following Gustilo et al[2].

The following demographic and clinical data were analyzed: sex, age, laterality, fracture-producing mechanism, fracture location, degree of comminution, open fracture type, associated injuries, initial evaluation of head and neck trauma (HNT) according to the Glasgow Coma Scale (GCS), time of surgery, type of surgical table and patient position, duration of surgery, nail type, use/non-use of reaming, type of interlocking used, need to open fracture site, number of transfusions, length of time in Intensive Care Unit, immediate and late complications, hospitalization time, secondary treatment, weight-bearing initiation, pain at final evaluation, hip and knee-joint balance, and walking difficulty.

A radiological multiobserver analysis was performed with the aim of evaluating rotational alterations, leg length discrepancy, heterotopic calcification and healing.

Quantitative variables were analyzed using Analysis of Variance (ANOVA), while categorical variables were analyzed with the chi square test. The level of statistical signification was fixed at ≤ 0.05. The statistical software used for the analysis was BMDP (Dixon, WJ, ed. BDMP *Statistical Software*. Vols. 1, 2. Berkeley: University of California Press; 1988), SPSS (SPSS 6.1 *Base system user's guide*. Chicago: SPSS Inc.; 1994) and EPIDAT 3.0. The study was sanctioned by our center's Committee of Ethics.

RESULTS

Male patients are predominant in our series (71%), the mean age being 26.9 years (range 14-85). Most of the cases are unilateral (96%), with a higher frequency of the left femur (57%).

In all cases the fractures were a consequence of a high energy trauma: 135 cases (86.6%) of motor vehicle accidents, 9 cases (5.8%) of fortuitous accidents, 3 cases (1.9%) of occupational accidents, 2 cases (1.3%) of falls and 1 (0.6%) sports accident.

In the classification by segments we observed the highest frequency of occurrence in the middle third (64.7%), followed by the distal third (19.3%) and, lastly, the proximal third (16%).

As regards comminution, we obtained the following distribution, according to the classification of Winquist and Hansen[1]: 35.9% grade III, 23.7% grade II, 22.4% grade I and 17.9% grade IV comminution.

In our series, there were 27 cases of open fractures (17%); 12 of these were grade I, 11 were grade II, and 4 were grade III-A, according to the classification of Gustilo et al[2].

Most of the patients (67%) presented with associated injuries (table 1), 59 patients (37.8%) needing surgical treatment.

We performed initial evaluation of HNT by means of GCS. Table 2 shows the distribution of HNT severity in relation to the moment of surgery.

Table 1. Injuries associated to diaphyseal femoral fracturesr

	Total number	Percentage
Fracture and/or displacement	77	51.3%
Head and neck trauma	43	28.6%
Thoracic trauma[a]	14	9.3%
Knee ligament injury[b]	12	8%
Abdominal trauma[c]	11	7.3%
Injury[d]	10	6.6%
Other	10	6.6%

[a]Direct trauma in the thoracic region, associated with rib, sternum and/or vertebral fractures.
[b]Injuries of knee ligaments with no bone damage or joint displacement at the moment of admission of the patient
[c]Excluding mild abdominal trauma (those without shock and with normal pO2).
[d]Excluding injuries due to open fracture.

Table 2. Head and neck trauma. Initial evaluation according to the Glasgow Coma Scale. Stratification at different moments during surgery

	Mild HNT[a]	Moderate HNT[b]	Severe HNT[c]
Patients treated < 48 h (n = 72)	62	10	0
Patients treated 48-120 h (n = 18)	16	2	0
Patients treated > 120 h (n = 60)	36	24	0

[a]Range 13-15 (Glasgow Coma Scale[GCS]). [b]Range 9-12 (ECG). [c]Range 3-8 (ECG). HNT: head and neck trauma.

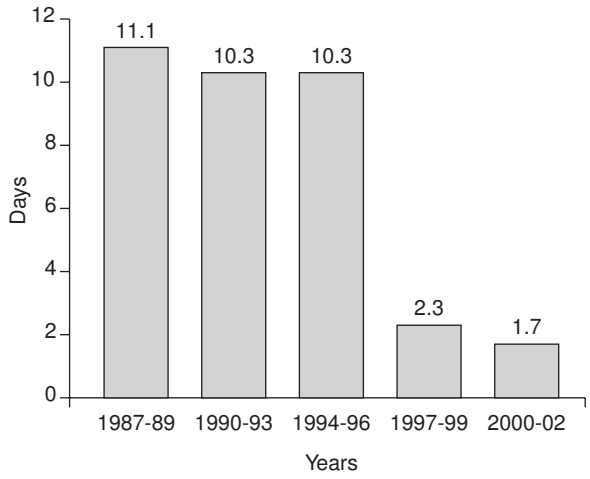

Figure 1. *Intramedullary nailing of the fracture. Mean time to surgery in different treatment periods.*

Figure 2. *Floating knee (associated homolateral tibial fracture). A retrograde nail was placed in the femur subsequent to the placement of an anterograde nail in the tibia using an single anterior approach.*

The time elapsed from the time of injury to surgery was 6.2 days (0-21). In cases in which the intramedullary nailing was delayed, we performed presurgical immobilization with skeletal traction.

Figure 1 shows the mean time to turgery in the different treatment periods. In all cases we performed pre-op antibiotic prophylaxis according to a pre-established protocol, as well as antibiotic treatment in the cases of open fractures.

Ninety-nine Grosse-Kempf (Howmedica) and 57 Russell-Taylor (Richards) nails were used, most of them reamed (82.7%). The diameter most frequently used was 12mm (55%). We performed intramedullary nailing of the retrograde femur in two patients with a homolateral tibial diaphyseal fracture (floating knee) (fig.2).

We used a traction table with the patient in the supine position in 137 cases (87.8), a standard table with the patient in the supine position in 18 cases (11.6%), and a traction table with the patient in the lateral position in only one case (0.6%). In 130 cases (83.3%) we used skeletal traction. In 4 cases (3%) it was necessary to open the fracture site to perform a reduction.

76.9% of the assemblies were static. The guided arc system was employed in the cases of proximal interlocking, whereas the free-hands technique was employed with distal interlocking.

The surgeries lasted 109.5 minutes on average (69-210 min.), from the moment the patient was placed in position to the closing of the incisions. The average duration in the group of patients operated on traction tables was 109.8 minutes (69-210 min.) whereas, in the group operated on standard tables, the average duration was 107.1 minutes (69-180 min.).

As regards the need of blood transfusions, 96 patients (62%) were given transfusions with an average of 2.5 (1-20) concentrates. Following surgery, 39 patients (26%) went into the Intensive Care Unit, where they remained an average of 4.3 (1-18) days.

The most frequent intraoperative complication was fracture in the area where the nail was introduced, which

Figure 3. *Fracture in the trochanteric region, as a result of introduction of intramedullary nail.*

happened in three cases (1.9%) (fig. 3), followed by false way in two cases (1.3%) and the breakage of the reamer in one case (0.6%). The most frequent postoperative complication was pain in the area where the nail was introduced (13.5%), followed by superficial infection (5.1%), nonunion (3.8%), fat embolism (2.6%), adult respiratory distress (2.6%), pneumonia (2.6%), pudendal nerve neuropraxia (2.6%), deep infection (1.3%) and foreign body granuloma (0.6%).

Postoperative breathing complications were analyzed by means of statistical correlations that took into account the type of complication, the patient group and the moment of surgical treatment (table 3).

The average time before initiating weight-bearing was 4.5 weeks (range 1-16).

Table 4. Repeated surgical procedures

	Total	Percentage
Distal dynamization[a]	9	5.8%
Nailing[b]	3	1.9%
Nail extraction due to infection[c]	2	1.3%

[a]Distal dynamization was indicated in cases of delayed consolidation. [b] New reamed nailing with wider diameter. [c]Nail extraction after nine months.

In twelve cases of nonunion or healing delay (7.7%) subsequent surgical treatment was needed to achieve final incorporation (table 4).

The average healing time was 3.4 months (2-10). Consolidation was achieved in all patients at the end of follow-up.

The patients' evolution with respect to pain is shown in figure 4: at the end of follow-up, 9 patients reported hip pain (5.8%), but there were no cases of pain in other areas.

Hip and knee-joint balance was complete at end of follow-up.

Following final consolidation, two patients (1.3%) presented with a 10 degree upper rotational deformity without clinical effects. In 17 cases (10.8%) we observed leg length discrepancies averaging 0.7 cm (0.5-1.7), all due to femoral shortening. No angular deformities were detected. In 14 patients (9%) we found heterotopic calcifications close to the place of entry of the intramedullary nail (fig.5).

At the end of follow-up the hardware was removed from 93 patients (59.6%), and there were no cases of refracture.

DISCUSSION

The demographic characteristics of our series do not differ from those of other series published by other authors[3-5], thus confirming a higher incidence in young male adults. Neither have we found any variation concerning the most frequent mechanism of injury which in our study too proved to be traffic accidents[3-5].

All the fractures were produced by high energy trauma. Associated injuries are frequent, and appear at a rate between 29 and 75% in the published series[3-5]. In our experience they accounted for 67% (table 1) and, as is made clear in

Table 3. Postoperative breathing complications

	ARDS	FES	PD	Pneumonia	Percentage
Patients treated < 48 h (n = 72)	1	0	2	0	4.16%
Patients treated 48-120 h (n = 18)	2	1	1	2	33.3%
Patients treated > 120 h (n = 60)	1	3	0	2	10%

ARDS: Adult Respiratory Distress Syndrome; FES: Fat Embolism Syndrome; PD: Pulmonary Dysfunction.

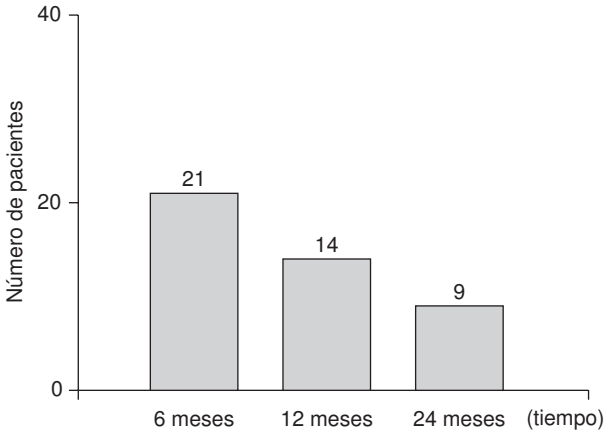

Figure 4. *Post-op pain. Cases with persistence of pain in relation to follow-up time.*

the bibliography, they were responsible for most of the side effects.

The 27 open femoral fractures in our series represented 17% of the total number. They were given treatment within the first six hours of referral to the center and unreamed nails were used in all cases. It has been claimed in some publications that results with these nails are not as good as with reamed nails[6]; however, we still believe that this is a controversial issue[7-11]. In our experience, the use of unreamed nails is not associated with delays in healing. In open fractures, unreamed nailing lessens intramedullary aggression[9] and reduces OR time. Nevertheless, we should be prudent in regard to the timing and intensity of weight bearing so as to preclude the fatigue of the material used.

Mortality is not high. None of the patients in our series died, but death may be caused by open injuries, fat embolism, adult respiratory distress syndrome, or multiorganic failure, especially in the cases of multiple-trauma patients. Morbidity as well as death rates can be decreased by performing early fracture reduction and internal fixation[3], both of which will enable rapid postsurgical mobility.

The average time to surgery was 6.2 days. Analyzing time to surgery in the different treatment periods (fig.1), we observed an increase in the tendency to perform early nailing, that is to say nailing performed within the first 48 hours[12,13]. The aim of applying early nailing is to prevent the appearance of the Fat Embolism Syndrome (FES). For several years it was thought that the reaming of the medullary canal caused the introduction of fat emboli by pressure into the blood stream, which, on reaching the lungs, originated or aggravated the FES. Although several studies have shown that early stabilization of long-bone fractures reduces the incidence of the FES [12,13], these results are controversial due to a bias in the sampling of the analyzed series. It is only through prospective randomized studies that we can determine the extent to which reaming can worsen breathing complications[7,14-16].

Figure 5. *View of heterotopic calcifications in the hip following femoral nailing.*

The latest publications indicate that, in the case of hemodynamically unstable patients, nailing is harmful to the lungs[3]. Other authors, moreover, have measured pro-inflammatory enzymes[14,17,18] –which are indicators of systemic postoperative harm– observing that their number increases when emergency nailing is performed, which could entail an additional risk for the patient.

In our series (table 3), the group of patients that was treated surgically within the first 48 hours, bears a smaller risk of experiencing breathing complications than the group that was treated between the third and fifth days, with an 0.1 odds ratio (confidence interval [CI]: 95%, from 0.017 to 0.627) and p = 0.01according to the test of Fisher. In patients treated as from the sixth day, we also found a smaller risk of experiencing breathing complications in relation to the group treated between the third and fifth days, the odds ratio being 0.21 (CI: 95%, from 0.057 to 0.806) and p = 0.03 also according to the test of Fisher. This controversial issue, about which we have reached no final conclusion, is part of a larger concern: the initial assistance afforded the multiple-trauma patient[15,19]. In the cases in which the nailing constitutes an excessively aggressive technique, mainly due to the bleeding and the surgical time it requires, we must

opt for external fixation and leave full correction for a second surgical procedure[12,14,19-21]. This line of action responds to the notion of *damage control orthopedics*[14,19], which evaluates the most appropriate moment for treatment of multiple-trauma patients with fractures in the long bones and in whose cases surgery for the primary stabilization of those bones could add a further aggression to that of the accident.

Pape et al[14] have shown a sustained inflammatory reaction following emergency intramedullary nailing (< 24 hours), a condition which does not appear after initial external fixation or after conversion to intramedullary nailing. Although it was shown that initial femur stabilization by intramedullary nailing causes a severe inflammatory reaction, no major post-op complications were found in the group of patients treated by nailing within the first 24 hours.

We believe that *damage control orthopedics* is useful to diminish the additional impact that may be caused by femoral stabilization surgery and it may prove an adequate alternative for those patients under risk of post-traumatic complications.

Another controversial problem is that of patients with femoral fractures and severe HNT: the patient's hemodynamic stability must not be put at risk; intracranial pressure should be monitored and kept at normal levels[22]. If theses parameters are not adequate, emergency nailing of the fracture should be avoided[3,13,22].

In the light of the published results as well as of our experience, we believe that the treatment of femoral fractures in the case of an unstable multiple-trauma patient must be based on a consensus and approached from a multidisciplinary perspective, integrating specific therapeutic protocols for each particular organ and injury. In the case of stable patients, early mobility following femoral nailing prevents lung complications and reduces muscle atrophy and joint contractures[4].

As regards surgical procedure, various authors have described technical methods aimed at helping to prevent mistakes and reducing the duration of surgery[3,4]. Works have been published with results that point out the advantage of the standard table for reducing surgery time and making further treatment on the multiple-trauma patient easier[3,13,23,24]. In our case, the standard table was not used in delayed surgery, since the difficulty to reduce the fracture together with the risk of shortening would mar the advantages mentioned above[4].

Most of the nails were implanted through an anterior approach. Retrograde nails have evolved as a plausible alternative, though several authors refer to a higher percentage of nonunion and residual knee pain[25,26]. On the other hand, it has been observed that neither knee stiffness nor septic arthritis are significant problems after their implantation. Retrograde nailing has the advantage of improving alignment in distal diaphyseal fractures, thus reducing surgical time and diminishing bloss loss. In our hospital we apply retrograde nails in the cases of distal femur fractures (not included in this series) and of floating knee, in which cases we are able to perform both nailing procedures through only one incision (fig. 2). We believe that retrograde femoral nailing is especially indicated in fractures located in the distal third as well as for clinical situations in which proximal access is impossible or undesirable. The systematic use of retrograde nailing in isolated fractures of the femoral diaphysis should be restricted on account of the unknown long-term effects on the knee[25,26].

The use of skeletal transcondylar traction did not cause morbility of the knee and, similarly to what is expressed in the literature[3,4], we consider it useful in the control of femoral rotation and in the prevention of shortening[4], particularly in the cases when surgery must be delayed[3] and when the fracture is located in the distal third[4]. Traction must be performed under rigorous conditions of asepsis and in a position sufficiently distal and anterior so as not to interfere with the tip of the nail. The use of the traction table can cause nerve palsy by compression[3,13,27]: the perineal post may injure the femoral or pudendal nerves[20]. In our series we encountered four cases of pudendal nerve palsy that recovered during post-op. If we do not use traction, especially when the fracture site is comminuted, we preclude shortening, with the length of the contralateral femur as reference[3].

The most frequent postoperative complication was pain[27,28]. Heterotopic ossification was present in more than 20% of the cases of interlocked intramedullary nailing in the literature; in our series we had a 9% incidence. Its relation to pain is an issue under discussion[28]. The group of patients with heterotopic ossification in our series presents a higher possibility of suffering final pain, with an odds ratio of 19.1 (CI: 95%, from 4.373 to 83.996) and p = 0.0003 according to the test of Fisher. Even though we have obtained statistically significant results, we should increase the size of our sample in order to achieve greater statistical precision. Reaming may favor the formation of heterotopic calcifications in the gluteal region[10]; however, we have not found significant differences between reamed and unreamed nails in relation to the presence of calcifications. In our series, the extraction of the nail has solved the problem of pain in most of the cases[4,29].

Although the long-term effects of the presence of the intramedullary nail have not been clearly determined, we know that the risk of refracture_after the extraction of the nail is small compared with that of explanting an osteosynthesis plate[29]. In keeping with our protocol, we removed the nail in the cases of young patients (< 50 years of age) and of patients with pain accountable to the nail. The iatrogenic potential inherent in the removal of osteosynthesis material must not be underestimated [29].

Intramedullary interlocked nailing in diaphyseal femoral fractures yields satisfactory incorporation results in 99%

of the cases, bearing an infection index of 1%. Most of the published series on interlocked nailing report healing rates between 97 and 100%[3-5], which are in line with the results obtained in our series. Former reviews reported high nonunion rates following comminute fractures; however this correlation was not found in our series, nor in series recently published by other authors[3,4,30]. In comminuted fractures, static interlocked reamed nailing renders satisfactory consolidation indices, due to the fact that static locking eliminates the loss of postoperative fixation, which is secondary to comminuted fractures[7,30].

As has been published by Wolinsky et al[3,13], angular alterations appear most frequently in distal fractures, whereas shortening is most frequently found in comminuted fractures (grades III and IV according to Winquist and Hansen). Healing in an incorrect position might cause leg length discrepancy, walking anomalies and arthritic knee alterations[4,13]; severe cases can be treated by corrective osteotomy followed by static intramedullary interlocked nailing. No procedure of this kind was necessary in our series due to the fact that the deformities that appeared had no clinical sequelae.

In conclusion, early surgical treatment of stable patients reduced the incidence of immediate complications in our series. We obtained satisfactory clinical and radiological results, with a low rate of complications, by treating femoral shaft fractures by intramedullary interlocked nailing.

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Conflict of interests

The authors have declared that they have no competing interests.