*Acta Orthop. Belg.*, 2016, **82**, 854-860

*ORIGINAL STUDY*

# Anatomical and functional evaluation of diaphyseal femoral fractures in children under 6 years old

Ali Alhefzi, Dheidan Alshammari, Laurent Bund, Ludovic Schneider, Philippe Gicquel

*Service de Chirurgie Pédiatrique, Hôpitaux Universitaires de Strasbourg, 1 avenue Molière, 67098 Strasbourg Cedex*

***Objective :*** **The aim of this study is to evaluate both the anatomical and functional consequences of our treatment protocol of diaphyseal femoral fractures in children under 6 years old**

***Methods :*** **We conducted a retrospective analysis of a series containing 50 children in Strasbourg University Hospital whom had traumatic diaphyseal femoral fractures and underwent conservative treatment by traction followed by casting with a mean follow-up period of 25 months.**

***Results :*** **All fractures healed without complications i.e. gait disorders, back pain and limitation of activity. Results showed a significant correlation between the initial varus angulation and shortening which could influence the final remodeling result within the first 24 months. Using the Receiver Operating Characteristic curve, we developed the Initial Displacement Index on Traction (IDIT) which is the sum of both the initial varus in degrees and the initial shortening in millimeters.**

***Conclusion :*** **The treatment by initial traction followed by a cast for childrens ≤ 6 years old gives clinical and radiological results comparable with those reported for immediate casting method. The hospitalization period is longer in the traction method but with less exposure to general anesthesia (GA) and risks of secondary displacements.**

## INTRODUCTION

Femoral fractures are the third most frequently diaphyseal fractures seen in childhood *(12)*. One of the most common complication of femoral shaft fractures in children is leg length discrepancy (LLD) *(19)*. This discrepancy is mainly caused by the initial deformation (shortening & axial deviations) which is compensated by the overgrowth of the affected femur *(8)*. Its significance arises when the difference of lengths is more than 1.5-2cm especially if it causes gait disorder which is a potential causes of back pain *(14)*. The second common complication following conservative treatment is axial deviation. There is a debate in the literature concerning the

■ Ali Alhefzi[1,2]
■ Dheidan Alshammari[1]
■ Laurent Bund[1]
■ Ludovic Schneider[1]
■ Philippe Gicquel[1]

[1]*Service de Chirurgie Pédiatrique, Hôpitaux Universitaires de Strasbourg, 1 avenue Molière, 67098 Strasbourg Cedex.*
[2]*College of Medicine King Khalid University Saudi Arabia Abha 61421, PO box 641.*

Correspondence : Ali Alhefzi, Service de Chirurgie Pédiatrique, Hôpitaux Universitaires de Strasbourg, 1 avenue Molière, 67098 Strasbourg Cedex.
E-mail : alhefzi@yahoo.com


*No benefits or funds were received in support of this study.*
*The authors report no conflict of interests.*

tolerable LLD & angular deformity. Metaizeau (2006) accepts 30° of initial axial deviation on any planes (coronal and sagittal) and 25mm shortening up to 2 years old, and he accepts 15° of coronal and 20° of sagittal angulations and 20mm shortening from 2-6 years old *(17)*. On the other hand, other authors are concerning the initial acceptable shortening limit which could be remodeled *(1,11,18)*. There are two different types of conservative treatment either immediate casting or traction for a certain period followed by casting. In recent years, most of the centers in France adopted the immediate casting method of treatment, however, in our center we continue with the other method.

The objectives of this study are : To assess femoral varus-valgus angulation and/or any leg length discrepancy at follow-up. To functionally evaluate articular range of motion and walking. To find relations between different deformation parameters and compare between the different methods of treatments.

We hypothesize that conservative treatment by traction followed by casting gives better clinical and radiological results.

## MATERIALS AND METHODS

A comprehensive review of our University Hospital database for all femoral fractures patients who were treated conservatively between the period of 2004-2011 in children ≤ 6 years old was carried out. Recruitment of study participants has been selected under the following inclusion and exclusion criteria:

Inclusion criteria: Traumatic, unilateral, middle-third fractures in children up to age of 6 years.

Exclusion criteria: Multiple fractures, pathological fractures, past medical history of previous lower limb fractures & less than 6 months of follow-up.

Following the above criteria, a total of 50 patients including 10 females and 40 males with an average follow up of 25.0±13.4 months (6-62) were found. The mean age of the study sample was 29.4±13.5 months (0-55). The most common cause of femoral fractures was falling from standing height (72%) amongst other causes like domestic violence (8%), road traffic accidents (4%), direct trauma (6%) and obstetric delivery (2%). (8%) of fractures were of an unknown cause.

Concerning the displacements and types of fractures in our series we found 40 patients (90%) with displaced non comminuted fracture, 4 patients (8%) with undisplaced non comminuted fracture, 1 patient (2%) with displaced comminuted fracture, 42 patients (84%) with spiral fracture, 5 patients (10%) with oblique, and 3 patients (6%) with transverse fractures.

The duration of hospitalization and traction varied amongst patients, however, the average traction period was 16.5 (± 6) days and the average duration of hospitalization was 17.4 (± 6) days. The total period of immobilization which includes the period of traction was 6.3 (± 1) weeks. 20 patients (40%) had spica cast applied under general anesthesia whereas 30 of patients (60%) had spica cast applied under sedation in the operating theatre. Also 30 (60%) of the fractures occurred in the right side whilst 20 (40%) occurred in the left side.

A retrospective analysis of x-rays and clinical information was performed which were collected from patient notes while followed in outpatient clinic. Initial femoral shortening and varus angulation were determined with x-ray of femur on traction in a duration of 2-3 weeks after the accident. Follow-up leg length discrepancy and varus angulation were determined with frontal telemetric x-ray. Functional assessment was determined by pain evaluation, walking difficulties, limitation of daily activities and range of motion of the hip and knee.

Table I. — Types of fractures

| Type of Fracture | Displaced non comminuted | Undiplaced non Comminuted | Displacecd Comminuted | Undisplaced Comminuted |
|---|---|---|---|---|
| Spiral Fracture | 40 ( 80%) | 2 (4%) | 0 (0%) | 0 (0%) |
| Oblique | 4 (8%) | 0 (0%) | 1 (2%) | 0 (0%) |
| Transverse | 1(2%) | 2(4%) | 0 (0%) | 0 (0%) |

## Statistical analysis

Data was collected and verified, variables were coded and entered with adequate backups. Both categorical variables and continuous variables were handled. Descriptive statistics, e.g., numbers, proportions, cumulative proportions, mean and standard deviation, was displayed, as appropriate.

Analytically, parametric techniques, e.g., t-test, Analysis of Variance (ANOVA) and Pearson's coefficient have been attempted, as applicable, analyzing normally distributed variables. Non-parametric alternatives, e.g., Mann Whitney *U* test, Kruskal-Wallis were used.

For qualitative variables; $\chi^2$ test of independence or Fisher's exact tests were used measuring the association between two sets of categorical data.

The limit value concerning the initial tolerable shortening and varus angulation was made by ROC curve (Receiver Operating Characteristic).

Level of significance was set to *p*-value <0.05. StatEL (www.adscience.eu) software was used for the analysis.

# RESULTS

## Functional

All fractures healed. All patients had good clinical and functional results, there was no complications (i.e. limping, walking difficulties or back pain) with all patients having a full range of motion of both hips and knees. None of the patients required any further surgical interventions (epiphysiodesis or corrective osteotomy).

## Radiological

*Correction of length & angulation:*

The average initial shortening was 12.4 ± 7.7 mm (0-31). Leg length discrepancy at 25 months was 3.9 ± 6.6 mm (0-15). The correction was found significant (*p*<0.00001) between the initial average value and those at 25 months of follow-up. The physiological limit, used, for leg length discrepancy was 10 mm. In this series 5 cases were found of whom still had >10 mm of difference by the end of 25 month of follow-up. However, as none of them exceeded 15 mm nor had any gait problems no surgical interventions were indicated.

Furthermore, the average initial femoral varus angulation was 10.6° ± 7.3° (0-25°). Femoral varus angulation at 25 month of follow-up was 2.6° ± 5.7° (0-20°). The correction at the 25-months period was also found significant (*p*<0.00001). The used physiological limit for femoral varus was 5°. Between patients, 14 patients had >5°, 7 of them had >10°. None of the previously mentioned exceeded >20° therefore no surgical indication was needed, especially with the absence of any clinical or functional consequences, patients who still have >10° of varus angulation are being followed.

No significant correlation between the initial and 25 months shortening was found, as well as for the initial and 25 months varus.

Regarding values of correction between the different periods of follow-up (6,12,18,24,30,36 and 48 months) a significant correlation between the initial values and the values of 6, 12 and 18 months was found, either concerning leg length discrepancy (*p*<0.00001 at 6 months, *p*<0.002 at 12 months and *p*<0.00002 at 18 months) or for the femoral varus angulation (*p*<0.00001 at 6 months, *p*<0.01

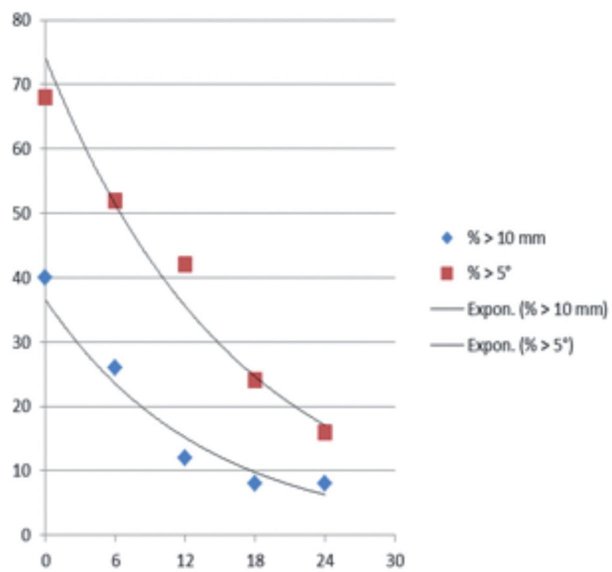


***Fig. 1.*** — Shows significant remodeling within the first 18 months.

at 12 months and $p<0.02$ at 18 months). Comparing different periods was no longer significant at 24 months. A significant correlation between the initial shortening and the initial varus was also found which became insignificant at 25 months.

Additionally, no significant correlation was found between the age at the time of the fracture and the correction period (either for shortening or varus). The average correction is 0.4 ± 0.2 mm / month concerning the length discrepancy and 0.9 ± 0.7 degrees/month for the varus angulation.

*Remodeling scheme*

Remodeling can be appreciated within the first 24 months.Whilst further studying the patients deemed not to be in acceptable correction (shortening >10 mm or varus >5 degrees) results related to remodeling can be drawn as follows:

1. Distribution analysis between the corrected and non-corrected patients depending on the delay was significantly different either for shortening or for the varus. ($p<0.00004$) and ($p<0.00001$) respectively.
2. Significant remodeling occurred in the first 18 months, as no significant correlation was detected between initial values and those after 24 months.

*Limit value:*

To further explore the data, a ROC curve was drawn from the initial displacement values (shortening & varus) and the corrected and non-corrected characters of deformation (i.e. the limit are 10mm for the shortening and 5 degrees for the varus) in 25 months of follow-up.

It was found that for initial shortening (measured on traction) the limit value was 18mm. The initial shortening should be less than 19mm in order to achieve a correction with length discrepancy <10mm in 25 months of follow-up.

It was also found that initial femoral varus (measured on traction) limit value is 12 degrees. The initial varus should be less than 13 degrees in order to achieve correction of 5 degrees in 25 months of follow-up.

The initial shortening and femoral varus (measured on traction) were significantly correlated ($p<0.01$), it was combined in an index named (Initial Displacement Index on Traction) IDIT= shortening in mm + varus in degrees (ROC curve coefficient). The limit value for this index was found to be 24.

To have a complete physiological correction (shortening <10 mm and varus <5 degrees) in 25 months of follow-up the IDIT should be less than 25.

## DISCUSSION

In pediatric traumatology, femoral fractures are reported to make 1.6% of all bony lesions *(11)*.

More recently, spica cast immobilization after traction for some period or immediately after reduction are the most commonly used conservative treatment for femoral fractures in preschool aged children *(1,6,9)*. In our center, all femoral shaft fractures are treated conservatively in children under the age of 6 with traction for around 2 weeks then hip spica is applied.

All patients in this study were managed conservatively without any patient requiring secondary surgical intervention. The conservative treatment of diaphyseal femoral fractures in children without any serious metabolic disorder and whom are under the age of 6 is more popular than the surgical one *(6)*, although some centers outside France adopted primary surgical treatment with elastic stable intramedullary nailing (ESIN) *(10)*. Moreover, our management protocol is supported by the fact that in this series, no patients had any functional problems in 24 months follow-up, furthermore, no patients needed to have a secondary intervention. Also, 40% of patients had to undergo casting under GA. However, no additional exposure to GA will be required to remove the cast.On the contrary, a second GA is usually required to remove nails in ESIN, as reported that 65% of ESIN were removed under GA *(10)*. On the other hand, GA will be necessary in almost all cases of immediate hip spica application, however, a remarkable reduction in hospital length of stay will be achieved *(2,9)*.

Furthermore, according to Berne et al. *(2)* an elevated risk of secondary displacement can be reach to up to 27% with 8% of revision under a second GA.

Buehler et al. *(4)* reported an (18%) of unacceptable shortening within 4 weeks of follow-up. Moreover, Illgen et al. *(13)* noted that a 20% loss of reduction and a 15% incidence of significant skin complications for early Spica application.

Given the above facts, there are some drawbacks associated with conservative management approach. Many discharged patients with spica casting will not be able to go to baby centers as they do not accept them with a cast *(10)*. This can put an extra load on parents in terms of time of work and pay loss. Additionally, some studies demonstrated a delayed time to full mobilization and returning to normal activity in the treatment group of spica casting whilst comparing them to ESIN treatment group *(10)*. Another possible disadvantage, is the cost and duration of hospitalization. An average of 17.4 days of hospitalization in this current study were noted which represents a potential challenge especially given the rising cost of medical care in front of the numerous financial challenges that medical systems face.

Cast associated complications can also occur with spica casting, Difazio et al. *(7)* documented a 28% of skin complications in a series of 297 children treated with spica casting for femoral fractures. This current study also showed that no patient presented with compartment syndrome, however, evidence does exist suggesting the occurrence of the latter in early spica casting *(15)* There is an early possible postoperative complication for the surgical treatment as noted by Bopst et al. *(3)* that (12.3%) of nail exteriorization and (1.4%) of local skin infection.

Amongst the most debilitating long term complications post conservative management of femoral fractures are angular & rotational deformities as there is no general agreement concerning the limits of tolerance of such deformities *(6)*. According to a study up to 15° angular malalignment and 20° rotational malalignment and 20mm shortening are acceptable in children up to the age of 6 years *(6)*. A number of patients who did not achieve acceptable correction rates were found in this study– in terms of varus, 16% of patients did not achieve correction; and in terms of length discrepancy, 8% did not, in which is comparable to Burton et al. *(5)* series with 5% of shortening and Malkawi et al. *(16)* series which showed 2% of discrepancy. Berne et al. *(2)* found in their series of 47 patients treated with immediate hip spica application that 10.5% of patients did not achieve leg length correction and 14.5% did not achieve angular correction.

It certainly is important to note, that even with the usage of ESIN to treat femoral fractures, length discrepancy or angle problems are inevitable *(6,10)*. In a study that reviewed 72 patients treated surgically there was one patient with an angular problem of over 5 degrees and 27 children with length discrepancy (overgrowth) of which 6 was above 1 cm *(3)*. However, the previous study was not inclusive to treating mid-shaft fractures as 64/72 fractures were mid-shaft. Another large clinical series that compared ESIN to spica casting in children between the ages of 2-6 years found that on the final follow-up that the two treatment groups had acceptable angulation, hence non requiring a surgical inter-

Table II. — Pros and cons

| Conservative Treatment | | Surgical Intervention | |
|---|---|---|---|
| Advantage | Disadvantage | Advantage | Disadvantage |
| Decreased need to undergo GA | Delay in order to achieve full activity | Less pressure on the family | Increased likelihood to have GA two times, the second being for nail removal |
| No Operative risks | Parents take time off work | Faster Ambulation | Risks of GA |
| | Cost of hospitalization | Faster return to activity | Operative risks |
| | Delayed return to activity | Shorter hospitalization | |
| | Longer Hospitalization | | |
| | Cast associated Complication like skin irritation | | |


*Fig. 2A.* — X-ray of a patient under traction with IDIT=44..

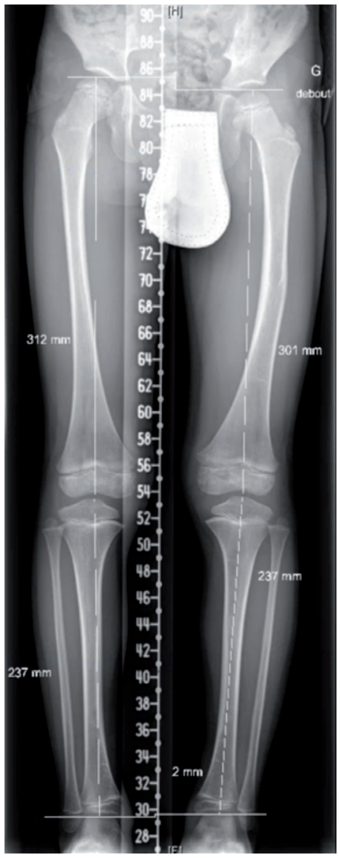


*Fig. 2B.* — X-ray of the same patient 48 months after fracture shows residual shortening (11mm) and varus deformation (10°)..

vention. (Spica 7.7 ± 6.5 vs. ESIN 4.9±4.1 degrees, *p*=0.002) coronal plane (Spica 4.8±5.5 vs. ESIN 2.2±2.4 degrees, *p*=0.006) *(10)*. The same remains true for length discrepancy where 3% of patients treated with spica casting had a length discrepancy of more than 2cm whereas it occurred in 1% of patients treated with ESIN. Again none of the patients required surgical intervention *(10)* .

These values were considered clinically acceptable and did not require any treatment. In this study we developed IDIT index (initial displacement index on traction) with a limit value of 25. A previous study noted that the risk of limb shortening is 20.4 times as high as in cases that present with initial shortening above 30mm *(6)* , however, in IDIT index an incorporation of both the initial difference of longer and angular deformation is measured.

One of the limitations in this study is that the axial deviation in sagittal plane was not taken in consideration because lateral views in the follow-up x-rays were not available. Another limitation is that the initial shortening was determined only on the femur, however, on the following follow-ups total length discrepancy was taken into account whilst determining whether it is acceptable or not. Also, there was no other groups to compare the results with our treatment method, that is mainly referred to the study feasibility.

We recommend to apply this index as a predictable measure for the final remolding results and we claim that this index could be further improved to include axial deviation in sagittal plane. Also we recommend to redefine the indications for those types of fractures to include both surgical and immediate hip casting according to the initial parameters.

## CONCLUSION

The treatment by traction for childrens ≤ 6 years old gives clinical and radiological results comparable with those of immediate casting method. The hospitalization period is longer in the traction method but with less exposure to general anesthesia (GA) and risks of secondary displacements. The essential correction period is within the first 2 years from the date of the fracture. IDIT more than 25 gives a prediction of residual deformation at least within the first 2 post-traumatic years.

### Compliance with Ethical Standards:

All authors declare that they have no conflict of interest.

This study was approved by the University of Strasbourg Hospitals Ethical Committee.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

## REFERENCES


1. **Akşahin E, Celebi L, Yüksel HY, Hapa O, Muratli HH, Aktekin CN**, et al. Immediate incorporated hip spica casting in pediatric femoral fractures: comparison of efficacy between normal and high-risk groups. *J Pediatr Orthop*. 2009 ; 29(1) : 39-43.
2. **Berne D, Mary P, Damsin J-PP, Filipe G**. Femoral shaft fracture in children: treatment with early spica cast. *Rev Chir Orthop Reparatrice Appar Mot*. 2003 ; 89(7) : 599-604.
3. **Bopst L, Reinberg O, Lutz N**. Femur fracture in preschool children: experience with flexible intramedullary nailing in 72 children. *J Pediatr Orthop*. 2007 ; 27(3) : 299-303.
4. **Buehler KC, Thompson JD, Sponseller PD, Black BE, Buckley SL, Griffin PP.** A prospective study of early spica casting outcomes in the treatment of femoral shaft fractures in children. *J Pediatr Orthop*. 1995 ; 15(1) : 30-5.
5. **Burton VW, Fordyce AJ**. Immobilization of femoral shaft fractures in children aged 2-10 years. *Injury*. 1972 ; 4(1) : 47-53.
6. **Catena N, Sénès FM, Riganti S, Boero S.** Diaphyseal femoral fractures below the age of six years: Results of plaster application and long term followup. *Indian J Orthop*. 2014 ; 48(1) : 30-4.
7. **DiFazio R, Vessey J, Zurakowski D, Hresko MT, Matheney T.** Incidence of skin complications and associated charges in children treated with hip spica casts for femur fractures. *J Pediatr Ortho*p. 2011 ; 31(1) : 17-22.
8. **Edvardsen P, Syversen SM**. Overgrowth of the femur after fracture of the shaft in childhood. *J Bone Joint Surg Br.* 1976 ; 58(3) : 339-42.
9. **Ferguson J, Nicol RO**. Early spica treatment of pediatric femoral shaft fractures. *J Pediatr Orthop*. 2000 ; 20(2) : 189-92.
10. **Heffernan MJ, Gordon JE, Sabatini CS, Keeler KA, Lehmann CL, O'Donnell JC, *et al***. Treatment of femur fractures in young children: a multicenter comparison of flexible intramedullary nails to spica casting in young children aged 2 to 6 years. *J Pediatr Orthop*. 2015 ; 35(2) : 126-9.
11. **Frech-Dörfler M, Hasler CC, Häcker F-MM**. Immediate hip spica for unstable femoral shaft fractures in preschool children: still an efficient and effective option. *Eur J Pediatr Surg*. 2010 ; 20(1) : 18-23.
12. **Hunter JB**. Femoral shaft fractures in children. *Injury* 2005 ; 36 Suppl 1 : 86-93.
13. **Illgen R, Rodgers WB, Hresko MT, Waters PM, Zurakowski D, Kasser JR**. Femur fractures in children: treatment with early sitting spica casting. *J Pediatr Orthop*. 1998 ; 18(4) : 481-7.
14. **Knutson GA.** Anatomic and functional leg-length inequa-lity : a review and recommendation for clinical decision-making. Part I, anatomic leg-length inequality : prevalence, magnitude, effects and clinical significance. *Chiropr Osteopat*. 2005 ; 3: 11.
15. **Large TM, Frick SL.** Compartment syndrome of the leg after treatment of a femoral fracture with an early sitting spica cast. A report of two cases. *J Bone Joint Surg Am*. 2003 ; 85 : 2207-10.
16. **Malkawi H, Shannak A, Hadidi S**. Remodeling after femoral shaft fractures in children treated by the modified blount method. *J Pediatr Orthop* ; 6(4) : 421-9.
17. **Metaizeau J-P.** Fractures de la diaphyse fémorale chez l'enfant. Emc - Appareil Locomoteur. 2006;1(3):1-7.
18. **Staheli LT.** Femoral and tibial growth following femoral shaft fracture in childhood. *Clin. Orthop. Relat. Res*. 1967 ; 55 : 159-63.
19. **Truesdell ED.** Inequality of the lower extremities following fracture of the shaft of the femur in children. *Ann Surg* 1921 ; 74(4) : 498-500.