Early reduction versus skin traction in the orthopaedic treatment of femoral shaft fractures in children under 6 years old

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Abstract

Background Femoral shaft fractures occur very frequently in children, and their prognosis usually is good. Nonoperative treatment is the gold standard for children under 6 years because of the excellent bony union and the remodelling qualities.

Purpose The aim of this study was to compare two orthopaedic therapeutic methods: skin traction versus immediate reduction.

Materials and methods The study involved 35 children, divided into two groups: in group 1, treatment consisted of skin traction for 21 days followed by hip spica casting; in group 2, an immediate reduction with early hip spica casting was performed. The ranges of motion, the delay before weight bearing, the hospitalisation duration and the required amount of painkillers were recorded. We compared initial shortening, axial, sagittal and rotational alignment, and femoral length discrepancy. We calculated the injured femoral diaphysal overgrowth and correlated it to the fracture type and location and to the initial shortening. Economical variables were also studied.

Results The mean overgrowth was 8.9 mm in group 1 and 8.5 mm in group 2. Three years after the trauma, length discrepancy was 4 mm in group 1 and 1 mm in group 2. Hip spica casting leads to significant reductions in weight-bearing delay, hospitalisation duration and pain. The cost of treatment with skin traction was four times higher (24,472 euros) than that of immediate reduction (6,384 euros).

Discussion Our results are in accordance with the literature. The femoral overgrowth was proportional to the initial shortening. Masculine gender, an oblique fracture and injury of the lower third of the femur were associated with the greatest femoral overgrowth. During the first year of follow-up, the femoral length discrepancy hardly varied after immediate reduction (4 mm), whereas the overgrowth reached 6 mm after skin traction. Overall, immediate hip spica casting leads to significant reductions in weight-bearing delay, hospitalisation duration, complications and costs, while having similar clinical results as traction.

Keywords Femur · Fracture · Child · Immediate spica cast

Introduction

Femoral shaft fractures represent the third most common location of children's fractures, after those of the upper limbs. Generally, their prognosis is good due to the growth plate.

Nonoperative treatment is the gold standard for children under 6 years because of the excellent bone union and the remodelling qualities. However, the main complication of femoral shaft fracture is the leg length discrepancy, resulting from the overgrowth of the broken limb. This problem is reported by many authors whichever nonoperative treatment is used [1–3] and must be taken into account when choosing the therapeutic method.

This study analyses the results of two different nonoperative treatments of the femoral shaft fracture in children under 6 years. The first one, consisting of skin traction, is the most common in France [1, 2]. The second corresponds to an immediate reduction, under general anaesthesia, and early hip spica casting [6–8].

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In accordance with the current health policy that attempts to control health costs, economic considerations (duration of hospitalisation, of immobilization and of school absence) can influence the choice of treatment when the final results are equal [9].

For these reasons, we compared the clinical, radiological and economic results of these two therapeutic methods. The study hypothesis was that early hip spica casting could yield comparable or better results than skin traction, with lower costs.

Materials and methods

Between October 1994 and July 2005, 54 children aged less than 6 years (mean age 2.8 years; range: 3 months–5.7 years) were admitted to the Emergency Ward for femoral shaft fracture, isolated or not. Nineteen patients (tourists) were later excluded, having been lost to follow-up or treated secondarily in another hospital closer to their home. These 19 patients belonged to both groups in similar proportions. The study involved 35 children treated and followed up in our unit.

The left leg was injured 17 times and the right 18 times. All the fractures were closed, and no pathological fracture occurred. Fracture type and localisation are given in Table 1a and b. Fracture mechanisms are described in Table 2.

We compared two nonoperative methods of treatment:

- Group 1 was treated with unilateral vertical skin traction, with 10% of body weight, for 21 days. Radiological follow-up consisted of X-rays of the face and profile of the fractured femur at day 2, 8, 15 and 21 post-trauma to evaluate reduction and bone union. A hip spica cast was made after 21 days of traction, without general anaesthesia, just before the patient was

Table 1 (a) Fracture localisation; (b) fracture type

Site	Treatment	
	Skin traction	Spica cast
Proximal third	2	5
Middle third	12	15
Distal third	0	1
Type of the fracture	Treatment	
	Skin traction	Spica cast
Transverse	3	4
Long spiroid	9	5
Short spiroid	2	6
Oblique	0	6

Table 2 Mechanisms of femoral fractures

Mechanism	Treatment	
	Skin traction	Spica cast
Falls	3	10
Falls from height	6	5
Pedestrian–motor vehicle accidents	3	4
Child abuse	0	2
Others	2	0

returned home. It was changed during a consultation 1 month later after a radiological control.

- Group 2 was managed by immediate closed reduction under general anaesthesia and early hip spica casting immobilisation in an operating room, with the knee and ankle maintained at 90° flexion. Hip immobilization was set at 90° flexion and 50° abduction. Acceptable initial shortening after reduction was defined as 10 mm $\pm$ 5. Frontal, sagittal and rotational alignments were controlled under fluoroscopy (the thickness of the femoral cortical bone visible in fluoroscopy must be of identical thickness to either side of the fracture line). The hip was maintained in the same way whatever the fracture location. Final radiological assessment of alignment (sagittal and frontal) in/under the cast was made in the operating room under anaesthesia. Children returned home within 48 h, after an X-ray control. The cast could be wedged in case of a major angular deformity. All casts were changed 1 month after injury and replaced by a spica cast in a more physiological position after clinical and radiological assessment. Spica casts were then removed at 2 months, followed by clinical and radiological evaluation. In case of non-union, a third spica cast could be applied, with a control at 2 weeks and 1 month. In case of cast damage, a new spica cast was applied.

All tractions and casts were applied by two senior paediatric orthopaedic surgeons (JG and TEH).

After removal of the cast, physiotherapy was not systematic for either group, and children returned home with instructions for self-physiotherapy.

The children were separated into two groups depending on treatment:

- In group 1, between 1994 and 1999, 14 children benefited from skin traction.
- In group 2, between 1999 and 2005, 21 children were treated by immediate hip spica casting.

Among the 35 patients seen for follow-up evaluation, 24 were boys and 11 were girls.

In group 1, there were 4 girls and 10 boys. The average age was 3.2 years (1.11–5.73).

In group 2, there were 7 girls and 14 boys. The average age was 2.4 years (0.26–5.51).

The follow-up evaluation was done at an average of 38.5 months (24–96).

During hospitalisation, the clinical follow-up aimed at assessing the traction or cast tolerance, and at researching complications.

After a cast application, children returned to the hospital for clinical and radiological follow-up at 1, 2, 3 and 6 months and then annually, unless complications occurred. Radiographs of the affected femur were performed in coronal and sagittal planes until the 6th month. Afterwards, long-length X-rays standing were performed annually.

Pain was evaluated by the duration of analgesic and anti-inflammatory prescriptions after traction or early cast application.

After cast removal, we studied the ranges of motion (hip, knee and ankle) and the delay before weight bearing. At the end of the follow-up, we searched for possible limps.

The economic analysis included the duration of the hospital stay, the number of X-rays (from the time of fracture to 3 years after the trauma), the number of medical consultations (from the Emergency Ward to 3 years of follow-up) and the number of casts per child.

The results for the two treatment methods were compared radiologically by measuring the rotational and axial malalignment (frontal, sagittal). On each X-ray, we measured the length of the fractured femur (mm) and the uninjured one, the limits being the summit of the proximal femoral epiphysis and the intercondylar notch of the femur. Both tibias were also measured between the top of the articular pillar of the proximal tibia and the dome of the talus. These measurements were made on a view box with geometrics tools.

Using the fractured femoral length (a) and the uninjured one (b), we calculated the femoral length discrepancy (FLD): $FLD = a - b$, in mm. The other measured mathematic variables were the tibia lengths on the broken limb (c) and on the intact one (d), with the calculation of the tibial length discrepancy (TLD): $TLD = c - d$, in mm. A positive length discrepancy (FLD and TLD) means that the measured fractured limb is longer than the uninjured one, and the opposite if the result is negative. Finally, we calculated the total limb length discrepancy (calculated TLLD): $calculated\ TLLD = FLD + TLD$. We then measured it directly on the view box ($measured\ TLLD = distance\ between\ the\ proximal\ femoral\ epiphysis\ and\ the\ horizontal\ lining\ of\ the\ long-length\ X-rays\ standing\ on\ the\ fractured\ leg\ minus\ that\ on\ the\ uninjured\ one$). These variables are expressed as mean and extreme results (minimum; maximum).

The initial shortening was measured on a radiography done 48 h after the fracture. The femoral length discrepancy was calculated on the most recent of the long-length X-rays standing. With these variables, we calculated the femoral diaphyseal overgrowth according to Janish's method [10] by adding the initial shortening and the femoral length discrepancy. The cast removal and the possibility to walk again were authorized after the radiological proof of a bone union.

Statistical analysis

Results are expressed as mean and range values. Comparisons of quantitative parameters (varus, valgus, measured TLLD, calculated TLLD, duration of hospital stay, delay for weight bearing and for bone union, global cost) between the two patient groups were done with the Mann–Whitney test for unpaired groups. Comparisons of these parameters according to fracture type were done with the Kruskal–Wallis test. Data at 6 months and 1 year of follow-up for each patient were compared using the Wilcoxon signed rank test for paired groups. A logistic regression was performed to analyse the influence of initial shortening on bone overgrowth. Adjusted R squared values (adjusted R^2) are furnished. All statistical analyses were performed using Statview® software 5.0 for Windows (SAS Institute, Cary, NC). P values below 0.05 are considered to indicate statistical significance.

Results

Reduction

Mean shortening at 48 h was 10.1 mm after skin traction and 10.4 mm after early hip spica casting. One month later, it was, respectively, 1.5 and 0.9 mm.

There were 1.9° of frontal malalignment after 48 h of skin traction application and 2.5° after early reduction. One month later, we found 2.9° of frontal angulation in group 1 and 3.4° in group 2. During the 2 years of follow-up, this was not considered to have led to an unacceptable position for either group (Table 3).

Sagittal angulations measured 2 days after traction application were 1.9° for group 1 and 1.4° for group 2. One month later they were, respectively, 2.5° and 3.4° , and had not increased at 60 days of follow-up. Beyond the 3rd month of radiological follow-up, the sagittal malalignment could not be studied because only long-length X-rays standing were performed (Table 3).

Only one patient from group 2 required a wedging of the cast to improve the reduction.

Table 3 Evolution of frontal and sagittal deviations depending on treatment method

Deviation	48 h		1 month		2 months		6 months			1 year		
	Traction	Cast	Traction	Cast	Traction	Cast	Traction	Cast	<i>P</i>	Traction	Cast	<i>P</i>
Frontal	1.9°	2.5°	2.9°	3.4°	2.7°	3.2°	2.8°	3°	0.625	2.1°	3.2°	0.625
Sagittal	2°	1.5°	2.5°	3.4°	2.2°	3.2°	–	–	–	–	–	–

Pain

Children in group 1 received paracetamol for an average of 8.3 days, nalbuphine for 4.2 days and an anti-inflammatory for 5.3 days. The minimal duration of nalbuphine prescription was 1 day. In group 2, paracetamol was prescribed on average for 2.8 days, nalbuphine for 1.3 days and an anti-inflammatory for 2.2 days. For five children, nalbuphine was not required.

Duration of hospitalisation

The mean hospitalisation was 18.8 days (15–22) in group 1 and 2.8 days (1–10) in group 2 ($P < 0.0001$). No patient required a second reduction in the operating room during follow-up.

Bone union

The radiological union was obtained in 76.8 days (70–90) in group 1 and in 61.5 days (30–90) in group 2 ($P < 0.0001$). This corresponded to the cast immobilisation duration. At the latest follow-up, the range of motion of knees and hips were normal for both groups, and there were no child with a limp. There were no refractures in either group.

Weight bearing

Weight bearing was significantly earlier for group 2 [on day 61 (30–119)] than for group 1 [day 75 (50–91)], ($P = 0.0002$).

In group 2, four children were too young to have started walking at the time of fracture. They achieved it at the expected age of 12–18 months.

Complications

Skin complications after cast application in group 1 occurred in two cases (bedsores on the iliac crest and great trochanter), but they required no modification of the therapeutic strategy and resolved rapidly after local treatment. One child presented an unacceptable fracture shortening needing the removal of the traction. Early hip spica cast application was complicated for three children by a loss of

reduction, which was nevertheless radiologically acceptable (frontal deviation $<15^\circ$; sagittal deviation $<30^\circ$, [12]).

Bone overgrowth

Bone overgrowth for each treatment group is presented in Table 4. The possible influence of initial shortening was studied (Table 5). It is noteworthy that the treatment method did not have any significant influence on bone overgrowth, regardless of gender or initial shortening ($P > 0.05$ for every measure). There was no significant relationship between fracture type and bone overgrowth either ($P = 0.962$). However, regardless of treatment or fracture type, bone overgrowth was significantly associated with initial shortening (adjusted $R^2 = 0.26$; $P = 0.001$).

Frontal deviation

Frontal angulation was not influenced by the fracture type for either treatment group at 6 months or 1 year ($P > 0.05$ for every measure).

Leg length difference

Results at 6 months and 1 year are given in Table 6. Leg length difference was not influenced by the fracture type for either treatment group at 6 months or 1 year ($P > 0.05$ for every measure).

In group 1, 3 years after the fracture, FLD was 3 mm, TLLDm was 5.2 mm, and TLLDc was 4 mm. For group 2, 2 years after fracture, FLD was 0.4 mm, TLLDm was 0.8 mm, and TLLDc was 0.7 mm. Three years after fracture, FLD was 0 mm, TLLDm was 2 mm, and TLLDc was 1 mm. Only nine patients attended the 3-year follow-up visit.

Table 4 Measure of the bone overgrowth, depending on the treatment method

Bone overgrowth	Treatment		
	Traction (mm)	Cast (mm)	<i>P</i> value
All patients	8.9	7.9	0.469
Boys	10.1	8.7	0.608
Girls	5.6	5.8	0.488

Table 5 Relationship between bone overgrowth and initial shortening, according to the therapeutic method

Initial shortening (mm)	Treatment		
	Bone overgrowth		
	Traction (mm)	Cast (mm)	<i>P</i> value
<5		2	NA
5–10	8.7	5.8	0.591
>10	10.8	18	0.520

In group 1, for an initial shortening <5 mm, the overgrowth could not be calculated because there were too few children

Table 6 Evolution of the leg length discrepancy (mm) with time, depending on treatment method

(mm)	6 months			1 year		
	Traction	Cast	<i>P</i> value	Traction	Cast	<i>P</i> value
FLD	−7.1	−4	0.840	−1.1	−4	0.469
TLLDm	−4.6	−0.5	0.419	−1	−0.5	0.533
TLLDc	−5.9	−2.5	0.439	0.6	−1.8	0.533

FLD: femoral length discrepancy; TLD: tibial length discrepancy; TLLDm: measured leg length difference directly on the view box = distance between the proximal femoral epiphysis and the horizontal lining of the long-length X-rays standing on the fractured leg minus that on the uninjured one; TLLDc: calculated leg length difference = FLD + TLD. A positive length discrepancy means that the measured fractured limb is longer than the uninjured one, and the opposite if the result is negative

Economic evaluation

Children from group 1 had an average of 5.5 visits and 9.9 X-rays, and children from group 2 had 5.8 visits and 8.8 X-rays.

Concerning the number of casts, we made on average of 2.1 casts per child in group 1 and 2 hip spica casts in group 2. One patient from group 1 presented a bed sore requiring transformation of the hip spica cast into a groin to toe cast, and one child needed three different casts because of repeated dirtying by urine and diarrhoea. For two patients from group 2, we changed the second hip immobilisation into a groin to toe cast because of the low location of the fracture and the satisfactory radiological results.

Hospitalisation for a femoral shaft fracture costs 5,415 euros according to the common classification of medical acts (CCAM) in France, with or without using the operating room and provided that it last between 2 and 19 days. The cost difference between the two therapeutic methods was therefore due to the 19 days of hospitalisation on the one hand and the cost of using the operating room on the other. The cost of casts, X-rays and follow-up medical visits were identical in both groups. Using the operating room cost 968 euros, whereas, based on the activity

performed in 2005, one day of hospitalisation in our ward cost 1,003 euros.

We could therefore estimate that the nonoperative treatment by skin traction is an average of four times more expensive (24,472 euros) than the immediate reduction and early hip spica cast (6,384 euros), ($P < 0.0001$).

Discussion

This retrospective study found similar results to previous reports [11].

Since 1999, we systematically treated the closed femoral shaft fracture of children aged less than 6 years with immediate reduction and an early hip spica cast under general anaesthesia. This practice, initially controversial in children, has gained in recognition through the work of Neer and Cadman [12] and Dameron and Thompson [3]. Before applying it, one must have good knowledge of the phases of bone healing and remodelling in children [13, 14].

Kasser [15] considered that acceptable angulation for children younger than 6 years was 15° in the frontal plane (valgus/varus) and 30° in the sagittal plane. A greater angulation can be tolerated in the sagittal plane due to the natural anterior angulation of the femur. Remodelling of valgus deformity seems to be more complete than the varus deformity and could still occur 5 years after the fracture [16].

For both groups, we visualized a bidimensional axial deviation (sagittal and frontal), progressing in two phases. The maximal deviation seemed to occur during the 1st month of evolution. Beyond this, frontal angulations did not vary much, as after 2 years of follow-up, they had varied an average of 0.1° in group 2.

In 1921, Truesdell [17] described that the fracture healing process stimulates bone growth in femoral shaft fractures in children. For Shapiro [18], the overgrowth is independent of age and fracture level. Considering the initial shortening during the immediate reduction would prevent this overgrowth. Berne and Filipe [4] estimate that a shortening between 5 and 15 mm at the bone union prevents this phenomenon. In our study, the mean shortening was within these limits. If the initial reduction was not satisfactory, the cast was redone or a gypsotomy was carried out in order to obtain these criteria of good reduction.

Many authors have demonstrated that overgrowth occurs during the first 2 years following the trauma [18, 19] and is maximal between 3 and 7 years [20]. Others authors have shown a linear relationship between initial shortening and overgrowth [10, 17].

In this study, we observed for both groups that the overgrowth increased with the initial shortening. A greater

overgrowth seemed to be associated with male gender, oblique fractures and lesions of the lower third of the femur shaft. During the first year of follow-up, FLD did not vary for group 2 (mean shortening stayed at 4 mm), whereas the fractured femur grew an average of 6 mm in group 1. It is possible that the greater percentage of long spiroid fractures in the spica cast group might have some influence on the union delay and on the discrepancy. Despite this non-homogeneity, no differences were observed between the two groups of patients.

The plaster application technique is fundamental, as it is necessary obtain and maintain the bone reduction and prevent complications. Whatever the location of the fracture, we always made the same hip spica cast, with a 90° hip flexion, 50° hip abduction, and 90° knee and ankle flexion. According to Illgen and Rogers [5], a knee flexion in the spica cast less than 50° could increase the risk for secondary displacement. The 2-week period following the fracture seems to be a critical period for greater risk of loss of reduction [21] and therefore requires a close follow-up. Maintenance of a postoperative varus less than 5°, a valgus less than 10° and a flexion angulation less than 10° is recommended to maintain fracture reduction [5].

General anaesthesia contributes to successful reduction as it allows relaxation of muscle spasms and complete pain relief [22]. Cassinelli [6] used immediate hip spica casting in the emergency room for femoral fracture in children younger than 6 years, under conscious sedation, if there were no associated factors requiring admission (child abuse, polytrauma). In their series, 8.9% of the patients required a re-reduction in the operating room.

Skin traction and cast application are major factors for pain control. However, patients treated with traction needed more painkillers and anti-inflammatory treatment.

Czertak and Hennrikus [7] developed criteria defining failure of early hip spica casting as including shortening >2.5 cm or angular deformity not corrected by wedging of >5° varus, 15° valgus and 20° sagittal plane. They require the abandoning of the cast and the application of traction. In their series, fracture angulation while in the cast in a uniform direction (average of 5° of varus angulation and 7° of anterior bowing) was probably due to the action of the hamstring, iliopsoas and adductors muscles. A valgus mold should be applied to the cast at the fracture site to prevent varus deformity [7, 23, 24]. Angular deformity can be well controlled with a wedging of the cast.

Infante [8] showed that excellent results can be obtained using a hip spica cast for isolated femur fractures in children weighing 10–80 lbs, which corresponds to ages of 1–11 years.

In a systematic overview of the literature, Sanders [25] concluded that there is a statistically significant trend for paediatric orthopaedists to treat older children's femur

fractures operatively and younger ones' nonoperatively. In France, we commonly use the Metaizeau's technique beyond 6–7 years of age [26].

In 2000, Wright [27] did a critical overview of 1,217 articles (15 cohorts) on the treatment of pediatric femoral shaft fractures to determine if any method could be recommended over others. He concluded that early application of a spica cast involved lower costs and malunion rates than traction.

Newton and Mubarak [28] compared the cost of traction and immediate hip spica casting. Total estimated costs of hip spica and traction treatments were 5,500 and 21,000 dollars, respectively. We found the same results.

In 1997, Coyte [29] assessed the cost of an early hip spica cast and external fixation. Total estimated costs per case of uncomplicated external fixation and hip spica were 5,720 and 4,478 dollars, respectively. External fixation is almost 28% more expensive than an early hip spica cast due to the cost of the fixator, the operating room time and nursing care. If loss of reduction of the fracture was observed, a wedging raised the cost of hip spica cast to 4,561 dollars. In the event of unsuccessful reduction, a repeated closed reduction in the operating room raised the cost to 5,837 dollars.

In our unit, the nonoperative treatment of femoral shaft fracture by immediate hip spica cast was 3.8 times cheaper than the application of skin traction.

Conclusion

Isolated and closed femoral shaft fractures in children aged less than 6 years must be treated in a nonoperative way. Since 1999, we have treated them with an immediate hip spica immobilisation under general anaesthesia. With 7 years of follow-up, we consider this nonoperative method as the best one for this injury. Immediate hip spica casting indeed leads to significant reductions in weight-bearing delay, hospitalisation duration, complications and costs, while having similar clinical results as traction. The reduction and the application of the hip spica cast plaster must be done very carefully, and the follow-up must be strict. Considering these results, we recommend that immediate hip spica casting be considered as the gold standard for closed femoral shaft fracture in children younger than 6 years.

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