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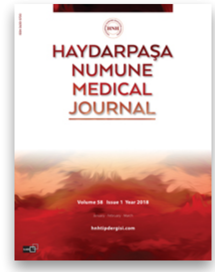

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ORIGINAL ARTICLE

Comparison of Angulation Deformity After Remodelling of Pediatric Femoral Fractures

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Abstract

Introduction: Although there is a consensus on the treatment of femoral shaft fractures in children aged <4 years and adolescents, the treatment method is still controversial for children between aged 4 and 10 years. Therefore, different kinds of treatment methods are described. The aim of the present study was to investigate the healing capacity of femoral shaft fractures in 4–10-year-old patients who were treated non-surgically and to compare the clinical and radiological results with the surgically treated patients in the same age group.

Methods: A total of 59 patients between aged 4 and 10 years were included in the study. The study included 18 (31%) females and 41 (69%) males. The mean age of the patients was 6.9 (4–10) years. The mean follow-up period was 84 (38–107) months. The mean ages of the non-surgical group (n=32) and the surgical group (n=27) were 5.9 and 7.1 years, respectively. The causes of fractures were falls from height (n=29), motor vehicle accidents (n=20), child abuse (n=1), and other causes (n=9).

Results: The improvement values at the angulation grades were significantly higher in anteroposterior and lateral radiographs in both groups (p<0.01). There was no significant difference between the groups in foot–thigh angle, foot progression angle, and leg length discrepancy (LLD). Fracture localization was not effective on LLD and clinical outcome success, and there was no significant difference between the two groups with regard to clinical outcomes.

Discussion and Conclusion: The immediate postoperative radiological reduction quality was significantly higher in the surgically treated group than in the non-surgically treated group in the early post-reduction. However, the differences of thigh–foot angles and foot progression angles between the groups were not statistically significant. In addition, there was no difference with regard to LLDs between the groups.

Keywords: Cast; Femur diaphysis; plate; screw; trauma.

Femoral shaft fractures represent 1.6% of all bony injuries in the pediatric population. The most common causes of these fractures are high-energy traumas, accidents, and falls from height [1–4]. Pediatric fractures have high potential of physiological healing and remodeling capacity. This remodeling capacity is higher with the tractional effect of physeal growth of long bones, such as femur, radius, and ulna. Femur shaft fractures, which have high remodeling properties, do not always heal without problems [5–7]. Leg length discrepancies (LLDs), coronal plane, sagittal plane,

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and rotational deformities can occur in spite of the appropriate treatment. Although angulation deformities can heal via remodeling, rotational deformities and limb length discrepancies cannot entirely recover. These can cause several problems in the later period of life [8]. The aim of the present study was to investigate the healing capacity of femoral shaft fractures in 4–10-year-old patients who were treated non-surgically and to compare the clinical and radiological results with the surgically treated patients in the same age group.

Materials and Methods

The study was approved by an Ethical Committee (HNHEAH-KAEK 2016/KK/83). We retrospectively reviewed 92 patients with femoral shaft fractures treated between January 2006 and December 2014. Patients with multiple injuries, accompanying lower limb fractures, brain and spinal cord traumas, and severe soft tissue injuries were excluded from the study. A total of 59 patients were included in the study. The study included 18 (31%) females and 41 (69%) males. The mean age of the patients was 6.9 (4–10) years. The mean follow-up period was 84 (38–107) months. The mean age of the non-surgical group (n=32) and surgical group (n=27) were 5.9 and 7.1 years, respectively. The causes of fractures were falls from height (n=29), motor vehicle accidents (n=20), child abuse (n=1), and other causes (n=9). There were 30 right and 29 left femoral fractures. Localization and types of fractures are shown in Tables 1 and 2.

All fractures were classified according to their localizations and fracture types. The patients were divided into two groups according to the treatment method. The non-surgical group was treated with skeletal traction and spica cast, and the surgical group was treated with plate fixation method. Final clinical and radiological evaluations of the patients were performed in the outpatient clinic. All of the femur anteroposterior (AP) and lateral (LAT) radiographies of the injured and uninjured sides were obtained from outpatient clinic follow-ups. Clinical evaluation was made by measuring thigh–foot angle and foot progression angle [9].

Table 1. Distribution of the fractures according to the localizations

Fracture localizations	n	%
Distal	10	16.9
Middle	39	66.1
Proximal	10	16.9
Total	59	100.0

Table 2. Distribution of fractures according to classification

Fracture type	n	%
Oblique	10	16.9
Comminuted	6	10.2
Spiral	20	33.9
Transverse	23	39.0
Total	59	100.0

Clinical evaluation procedure: Thigh–foot angle was measured on the prone position keeping the knees at 90° flexion and foot at neutral position. The angle on the bisecting point of the line passing the mid-thigh and the line between the heel and the 2nd toe was measured by using goniometer. Foot progression angle was estimated by selecting 10 of the footprints, after a child with the colored feet walked on a straight line. The median value of these 10 footprints was obtained as foot progression angle. The foot progression angle of the non-injured limb was considered as normal, and the deviation of the injured side from the normal values was measured. Positive values were considered as greater from the normal. Negative values were considered as smaller from the normal. The clinical and radiological outcomes were evaluated as very good, good, and poor. Very good was no clinical limb deformity, no limping, <5 mm clinical LLD, and radiologically <5° angulation in per plane. Good was <15 mm clinical LLD, no limping, and radiologically <15° angulation in per plane. Poor was >15 mm LLD, limping presentation, radiologically >15° angulation in per plane, and rotational deformity [10].

Skeletal traction and spica cast procedure: Proximal tibial skeletal traction was applied under local anesthesia at the level of the tuberositas tibia, and the pins were inserted from the LAT side to the medial to avoid peroneal nerve injury. Appropriate traction weight was applied depending on patient's weight and age. The AP and LAT radiographs of the femur were obtained weekly, and the traction weight was modified according to alignment. The spica cast was applied when the callus formation was observed on the radiographs. Spica cast was applied with 30° hip flexion and abduction and 20° knee flexion including the ankle on the injured side and ended above the knee on the contralateral side. The patients were followed up 3–6 weeks after applying spica cast, and the cast was removed when fracture healing was observed (Fig. 1).

Surgically treated patient's procedure: Open reduction and internal fixation were made by using titanium or steel dynamic compression plate. LAT longitudinal incision was used in all cases. Routine follow-ups were made on postoperative days 14, 30, and 90.

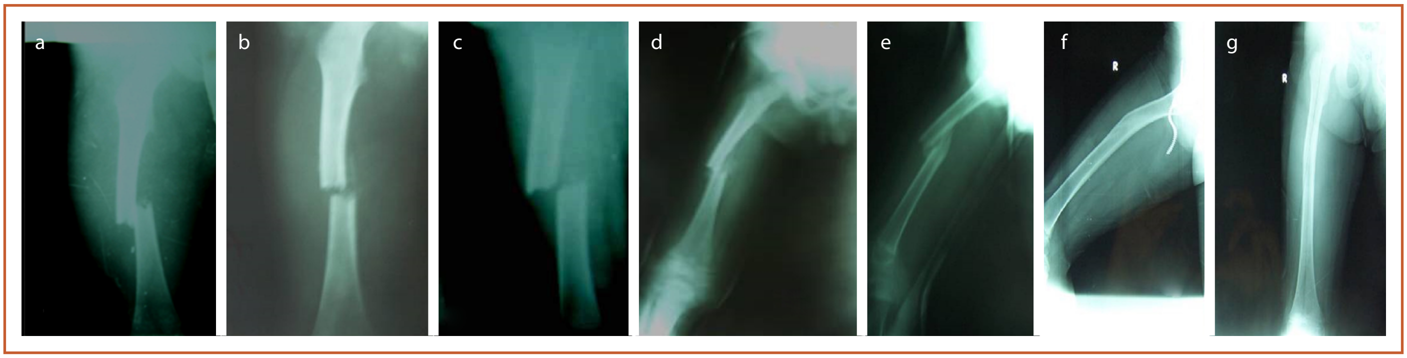

Figure 1. (a) 5-year-old boy, fall from height, first AP X-ray. **(b, c)** 12 days in skeletal traction AP and LAT. **(d, e)** 26 days in spica cast, AP angulation 167° and LAT 163° X-ray graph. **(f, g)** 4 years later, AP angulation 175° and LAT angulation 168°.

Statistical Analysis

Statistical analysis was performed using MedCalc statistical software version 12.7.7 (2013; MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org).

To describe continuous variations, descriptive statistics were used (medium, standard deviation, minimum, median, and maximum). Differential categorical data were compared using the chi-square test and Fisher–Freeman–Halton test. To compare independent normal distributed two samples, Student's t-test was used. To compare independent non-parametric two samples, Mann–Whitney U test was used. Paired sample t-test was used to compare dependent two samples, and Wilcoxon signed-rank test was used to compare dependent non-parametric two samples. A p value <0.05 was accepted as statistically significant.

Results

The correction of angulation degrees of AP and LAT radiographs in the latest follow-up was significantly higher in both groups (p<0.01). The correction of angulation degrees between the two groups was significantly higher in the surgically treated group (p<0.01) (Table 3).

The differences of thigh–foot angles and foot progression angles between the groups were not statistically significant. However, the length of hospitalization was significantly longer in the non-surgically treated group (Table 4). The dif-

Table 3. Radiographic outcomes of the groups

Groups	AP plane Mean±SD med (min-max)		LAT plane Mean±SD med (min-max)	
	Before	After	Before	After
Non surgical (n=32)	14.5±7.44	6.7±5.2	14.8±7.6	9.8±7.5
	15 (3-30)	(0-18)	15 (3-34)	10 (0-25.2)
Surgical (n=27)	18.9±6.9	0	18.9±5.6	0
	20 (10-40)		20 (10-30)	
p		<0.01*		<0.01*

*Wilcoxon signed-rank test.

Table 4. Clinical outcomes of the groups

Groups	Thigh-foot angle Mean±SD med (min-max)	Foot progression angle Mean±SD med (min-max)	Length of hospitalization (day) Mean±SD med (min-max)
Non-surgical (n=32)	1.5±6.8	(-) 0.12±3.2	17.8±4.6
	0 (-10-16)	0 (-10-7)	18 (9-33)
Surgical (n=27)	(-) 3.3±10.4	(-) 0.67±2.5	11.9±5.7
	0 (-20-10)	0 (-6-6)	12 (4-27)
p	0.121*	0.243*	<0.01**

*Mann–Whitney U test; **Student's t-test.

Table 5. The measurements of leg length discrepancies of the groups

	Non-surgical, n (%)		Surgical, n (%)		Total, n (%)	
Non- Equal	17 (53.1)		18 (66.7)		35 (59.3)	
Equal	15 (46.9)		9 (33.3)		24 (40.7)	
Total	32 (100)		27 (100)		59 (100)	
Shortening grups	**n**	**Mean***	**Med.***	**SD**	**Min.***	**Maks.***
Non-surgical	9	7.8	5	4.4	5	15
Surgical	6	12.7	15	4.3	5	16
Lengthening grups	**n**	**Mean***	**Med.***	**SD**	**Min.***	**Maks.***
Non-Surgical	8	15.25	10	14.9	5	50
Surgical	12	14.2	14.5	5.8	5	25

*: Millimeter value.

Table 6. Distribution of the outcomes

Clinical outcomes	Non-surgical, n (%)	Surgical, n (%)	p
Poor	2 (50.0)	2 (50.0)	0.425
Good	24 (60.0)	16 (40.0)	
Very good	6 (40.0)	9 (60.0)	

Fisher's exact test.

ferences of LLDs between the groups were not statistically significant (p=0.291) (Table 5). The differences in clinical outcomes between the groups were not statistically significant (p=0.425) (Table 6). It was also demonstrated that the LLD and the clinical outcomes were not related with the fracture localization.

In the non-surgical group, four patients had pin tract infections, and three cases were treated with local antiseptics and antibiotics. In one patient, skeletal traction was terminated early, followed by minimal wound debridement and splint, and union was achieved (Fig. 2). In one patient in the surgical group, an infection developed after removal of the implant. The patient was re-admitted and treated twice with debridement and parenteral antibiotherapy.

Discussion

Successful results were reported after non-surgical treatment of femoral shaft fractures in the pediatric population [11–13]. Surgical procedures were preferred in comminuted fractures and when accompanied multiple injuries are present. The most common surgical procedures performed between aged 4 and 10 years are (titanium) elastic nailing and plate fixation [14, 15]. Both surgical and non-surgical methods have advantages and disadvantages. However, recently, the indications of surgical methods are seen to be increasing due to complications of non-surgical methods, such as malunion, shortness, radiation exposure, length of hospitalization, and high cost [16–20]. Although there is a consensus in the treatment of femoral shaft fractures in children aged <5 years and in adolescents, the treatment method is still controversial for children between aged 4 and 10 years. In adolescents, the results of surgical methods are better than those of non-surgical methods [13, 15].

After healing of femoral shaft fractures, 1.5–2 cm LLD can be well tolerated between aged 4 and 10 years [16, 19, 21]. Hammad et al. reported that LLD is observed in 6 of 15 patients who were treated by dynamic compression plate [22]. Eren et al. reported that mean 1.2 cm LLD is observed in 10

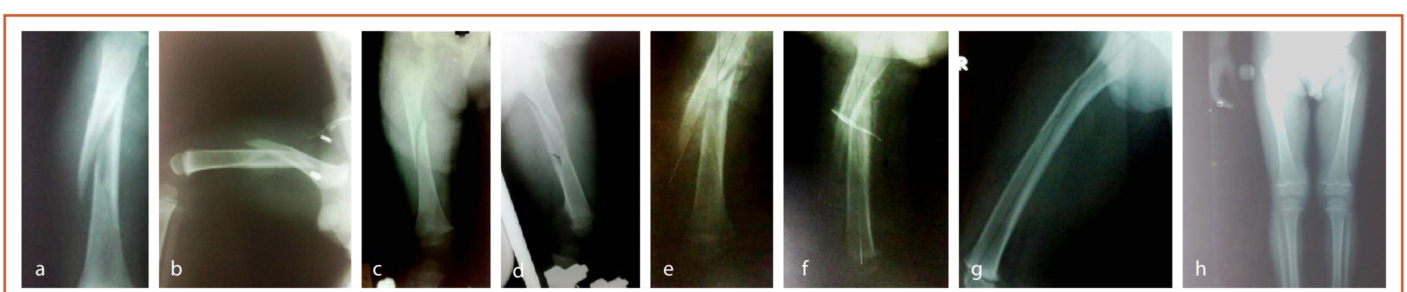

Figure 2. (a, b) 4-year-old boy, traffic accident, first AP, LAT X-ray. **(c, d)** 8 days skeletal traction finished by pin tract infection AP and LAT. **(e, f)** 20 days in spica cast, AP angulation 159° and LAT 156° X-ray graph. **(g, h)** 3 years later, AP angulation 178° and LAT angulation 175°.

of 35 patients who were treated by plate fixation [23]. In our study, LLD was observed in 53% of the non-surgical group and 66% of the surgical group. However, in both groups, <5% of the patients had an LLD >2 cm. LLD was affected by the quality of reduction in both groups. It was reported that after anatomical reduction, increase in bone vascularity during fracture healing resulted with overgrowth of the femur in surgical procedures [24–26]. In the current study, overgrowth of the femur was observed twice as much as shortened femur. In the non-surgical group, overgrowth and shortening rates were similar. It was reported that the angulation after the reduction of femoral shaft fractures was healed by remodeling via Wolf's law, particularly in proximal shaft fractures [5, 27–29]. In the present study, anatomical reduction was obtained in the surgical group. Although the residual angulation deformities that were <10° in both planes were seen in early radiographs in the non-surgical group, the correction of angulations was significant in the last follow-up. Stephens et al. [16] demonstrated in their study that angulations aged <10 years are completely corrected via remodeling, in which the patients are treated with non-surgical methods. Our thought is although the anatomical reduction cannot be obtained in non-surgical methods, low degrees of angulation can be tolerated because of intensive muscle and fat tissue of the thigh.

Other complications of pediatric femoral shaft fractures are rotational deformities that can be seen in both surgical and non-surgical methods [30, 31]. This situation clinically represents as lower extremity malalignments, limited hip range of motion, and gait problems. In the literature, rotational deformities were measured by using computed tomography (CT). In our study, CT was not preferred to avoid from high radiation exposure. Özel et al. described a method whereby rotational deformities can be measured by using direct radiography [32]. However, the accuracy of this method decreases in healed fractures. Therefore, we preferred to measure rotational deformities clinically. We found that the correction of rotational deformities was closer to anatomical alignment in the surgical group, and that the differences of both groups were not found to be statistically significant. Bulut et al. demonstrated 17 external rotation deformities and nine internal rotation deformities in the CT examination of 28 femur shaft fractures that were treated by non-surgical method and also reported >10° of rotational deformity in four patients [33]. In the pediatric population, <25° of rotational deformities of the femur can be well tolerated. Davids et al. [34] also reported that the rotational deformities after femoral fractures are not completely corrected. However, symmetric thigh–foot angles were regained with remodeling of soft tissues and joints. In our study, rotational deformities that caused clinical problems were not seen in both groups.

The major limitation of the present study is the number of patients. The patients were statistically enough to compare two methods, but more patients were needed for the comparison of subgroups with regard to fracture type. We believe that the study would be more powerful and specific if subgroup analysis could be studied. However, the surgical group, which only consisted of patients with plate fixation, makes the study more specific. Intramedullary nailed patients were excluded from the study because of the controversy of the nails in the correction of rotational deformities. Patients who were performed external fixator were also excluded. While the majority of these patients were subjected to multitrauma, the results could be misleading with regard to LLD.

Many treatment options are present for pediatric femoral fractures. Fortunately, outcomes are almost always great [7, 11, 15, 19]. However, LLDs and rotational and angulation deformities can be observed in all treatment types. In addition to these, surgical treatments have some disadvantages, such as secondary surgery for implant removal, need of a postoperative surgical site care, and cosmetic issues after wound healing (scarring).

The present study supports the hypothesis that there was no any difference between outcomes and clinical results of femur shaft fractures that were treated in two methods in aged 4–10 years. Although the early postoperative radiological reduction quality was significantly higher in the surgically treated group, the differences of clinical outcomes were not found to be statistically significant.

Ethics Committee Approval: The study was approved by local Ethical Committee (HNHEAH-KAEK 2016/KK/83).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: L.A.; Design: L.A., S.A.; Data Collection or Processing: L.A., H.B.; Analysis or Interpretation: T.M.D., E.B.; Literature Search: L.A., H.B.

Conflict of Interest: None declared.

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