Effect of rotational deformities after pediatric femoral fracture on clinical outcome

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Femoral shaft fractures are the most common pediatric injuries that require hospitalization. Early closed reduction and spica casting are one of the most popular treatment options. One of the significant complications of spica casting is rotational deformities of the fracture. The present study aimed to determine the potential effects of rotational deformities in pediatric patients who underwent early spica casting after a femoral shaft fracture. Pediatric patients who underwent early spica casting following femoral shaft fractures were screened retrospectively. Radiological measurements were made on the patients' initial postop radiographs who could be measured rotationally according to the defined radiological method. Twenty-three patients with more than 10° of rotation in their measurements were included in the study. Differences in leg length and rotation between both legs were calculated with clinical examination methods for all patients in the study. The gaits of the patients were observed; patient and family complaints were obtained. We found a strong and positive correlation between the rotational measurement made on the X-ray and the clinical measurement (*R*: 0.634, *P*: 0.001). For measurements made on X-ray, the mean rotational value was calculated as 27.2 ± 6.9 degrees. After the patients' clinical examination, an average of 3.0 ± 1.7 degrees rotational difference was found between the broken limb and the healthy limb. No patient or family complained of trauma. Early spica casting, according to the age of the patient, is an effective treatment method. There may still be certain degrees of deformity after treatment, but patients well tolerate them even at high degrees. Accordingly, it was concluded that the rotational deformities less than 30 degrees would not cause clinical problems on children under 4 years of age which may require postoperative revisions or the use of various costly imaging techniques and include radiation. *J Pediatr Orthop B* 31: e130–e134 Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.

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Introduction

Femoral shaft fractures constitute 1.6% of all bone damage in children and are the most common pediatric injuries that require hospitalization [1]. Treatment of femoral fractures mainly depends on the patient's age and size. Patient's weight, the presence of additional pathologies, the shape of the fracture, the surgeon's preference, and social and economic reasons are other factors that affect the treatment option [2,3]. Treatment options can be conservative in the form of hip spica casting or surgical with various options. Surgical treatment options include intramedullary fixation, plate and screw fixation, and external fixation, depending on the patient's age and the soft tissue condition. For patients aged between 6 months and 5 years with isolated femoral shaft fractures, early closed reduction and spica casting are recommended as standard treatment [4]. Significant complications of conservative treatment include angulation, shortness or length difference in fracture and rotational deformities. It is known that pediatric patients have varying degrees of remodeling capacities, depending on the location of the fracture and the age of the patient. Therefore, deformities up to certain degrees following femoral fractures in pediatrics are of no concern. Although the limits for coronal and sagittal plane deformities in femoral fractures are clearly stated in the literature, discussions about rotational deformities continue [1]. It is easier to recognize coronal and sagittal plane deformities than rotational plane deformities during surgery, and it is possible to correct these deformities with a perioperative intervention [5]. However, because rotational alignment is more difficult to evaluate and correct, residual rotational deformities may occur at certain degrees after surgery.

Our study aimed to evaluate the frequency and amount of rotational deformities in pediatric patients who underwent early spica casting after femoral shaft fracture, and the long-term reflection of this result on the early postop radiography.

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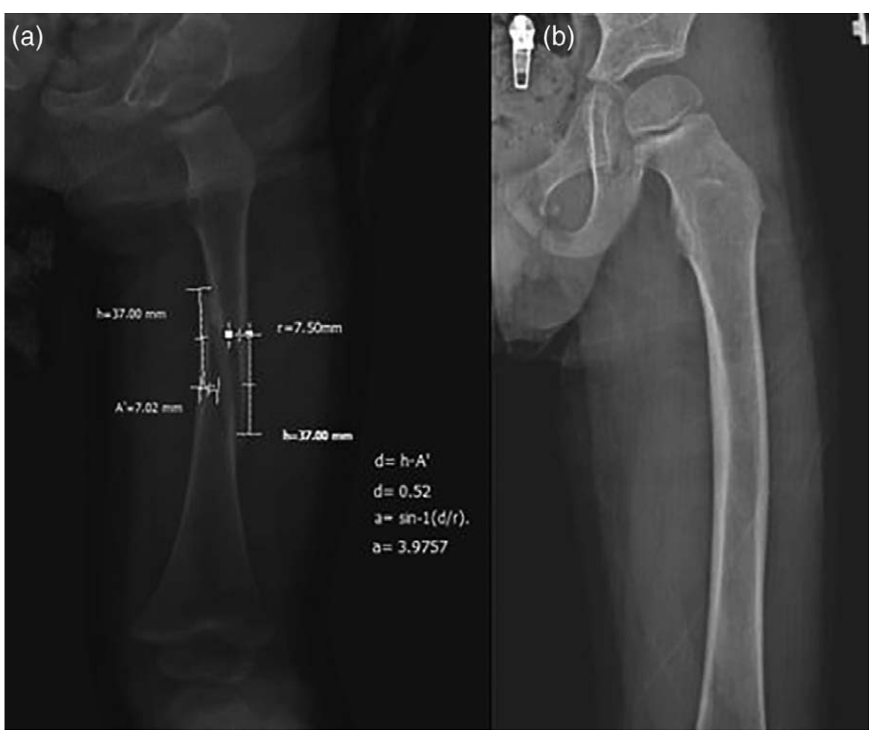
Materials and methods

Approval for this study was granted by our institution's ethics committee (protocol number: 09.2019.020 dated: 02.03.2019). The patients' respective parents were informed in detail about the study, and their written consent was obtained. Pediatric patients presented to the emergency department diagnosed with unilateral femoral shaft fracture between 2014 and 2018 were retrospectively screened. Patients who were treated surgically, did not come for routine control and underwent cast revision were excluded from the study. On the basis of the patients' early postop radiographs, the rotation was measured using the method described by Ozel *et al.* [6] (Fig. 1 a and b). Image analysis was conducted digitally using medical planning software (INFINITT PACS, Seoul, South Korea). Patients with inadequate radiographs for measurement, femoral bowing, nondisplaced fracture or absence of landmarks required for measurement were excluded from the study. Two independent researchers made measurements. The differences between the measurements made by the researchers were assessed by measuring them together again to reduce interobserver difference. According to rotational values, patients were divided into three groups as below 10 degrees, between 10 and 30 degrees, and above 30 degrees. Patients whose rotational values were calculated to be less than 10 degrees were excluded from the study because their effect on clinical results would not be significant. The remaining patients were contacted via telephone numbers registered on the system, and the patients were examined clinically. Apart from the radiographs taken during their routine controls, no new radiographs were taken, and the patients and their families were questioned on the basis of an examination form we created. During the examination, the patient's gait (presence of limping and gait disturbance) was evaluated, the length between both anterior superior iliac spines and the ipsilateral medial malleoli was measured in the supine position, and while the patients were in the prone position, with the knees flexed at 90 degrees and both legs in maximum internal rotation, rotation values of the leg were determined with a goniometer. To prevent pelvic tilting, an ortopedic resident held patient's both posterior superior iliak spine at the same level. To eliminate bilateral increased femoral anteversion, internal rotation difference between both legs was calculated as residual rotational deformity. Patients and their parents were questioned about their complaints related to trauma and all data recorded to the created form.

It was statistically evaluated whether there was a relationship between the increase in rotational deformity measured in postop early radiographs and gait disturbance in

Fig. 1



(a) Femur radiography of a 3-year-old patient with a rotational deformity of 33 degrees in the fracture line, measured on direct radiography taken after spica casting. (b) Femur radiography of the same patient after 2 years of follow-up, and clinical examination revealed 6 degrees of rotational difference between both lower limbs.

clinical follow-up, and the presence of rotation difference between the lower extremities.

Surgical technique and follow-up

In our clinic, taction before casting was not applied to any patient. Patients were operated within 24 h following the diagnosis, and spica casting was applied to all of them in the operating room under general anesthesia, after closed reduction with fluoroscopy control. Technically, all hip spica casts were done covering the broken leg up to the ankle, and the opposite limb up to the knee. During casting, hip flexion was kept between 60 and 90 degrees, and abduction was done up to 30 degrees. Knee flexion of more than 90 degrees was not applied to any patient and was kept around approximately 45 degrees on average. During casting, the varus–valgus angle, anterior–posterior angulation and shortening were kept under 15 degrees, under 20 degrees and under 2.5 cm, respectively, in all patients. Casts were removed between 4 and 8 weeks, depending on the patient's age, following the detection of sufficient union on plain radiographs taken during routine controls.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics v. 20 (SPSS Inc., Chicago, Illinois, USA) software. Results were stated with descriptive statistical methods (mean, SD). Pearson correlation analysis was used to examine the correlation between the measurements.

Results

The data of 63 patients were accessed through the system, and it was noted that 6 patients did not come for their routine controls and left the follow-up after casting. Therefore, these patients were excluded from the study. When the radiographs taken during the routine follow-up of the remaining 57 patients were examined, it was found that no patient was revised. Ten patients whose rotational calculations could not be performed with the method we used on early postop femur radiographs were excluded from the study. The fracture line's rotational values were calculated for the remaining 47 patients, and 24 patients whose measured rotational values were below 10 degrees were excluded from the study. Thus, 23 patients were included in the study.

The mean age of the patients at the time of fracture was 32.9 ± 13.5 months (min: 12 months, max: 66 months), 82.6% 19 (number of patients) were males, and 17.4% [4] were females. In the measurements made on the X-ray, 60.8% 14 (number of patients) of the patients were measured between 10 and 30 degrees, whereas 39.2% [9] were measured above 30 degrees. The mean rotational value was calculated as 27.2 ± 6.9 degrees in the measurements made on X-ray (min: 16 degrees, max: 38 degrees). Mean follow-up time after the fracture was 31.9 ± 15.4 months. After the examination and family interrogation, no complaints about the fracture or clinical findings such as limping or gait disturbance were found in any patient. After the clinical examination of the patients, an average of 3.0 ± 1.7 degrees difference was found between the broken side and the healthy side (min: 1 degree, max: 6 degrees). In the calculations, the average leg length difference was determined as 0.3 ± 0.3 cm. All but one patient with 5 degrees or more rotational difference had more internal rotation on fractured side, but these data were too few to make a statistical subgroup analysis. Demographic data and clinical features of the patient group are summarized in Table 1.

In the statistical analysis, there was a strong and positive correlation between the rotational measurement made on the X-ray and the clinical measurement (R: 0.634; P: 0.001). There was no significant relationship between the follow-up period and the rotational angle differences calculated clinically ($P > 0.05$). There was no significant relationship between the follow-up period and clinically measured leg length differences ($P > 0.05$) (Table 2).

Discussion

Although coronal and sagittal plane deformities recover spontaneously over time, it is thought that the remodeling potential of rotational deformities is very low [7]. The general consensus accepts deformities below 10 degrees, and it concentrates that these deformities do not show significant clinical symptoms and are well tolerated by the patients [5,8,9–12]. On the other hand, there are opinions in the literature indicating that femoral rotations can be clinically tolerated in patients with residual rotational deformities exceeding 10 degrees after fracture, due to soft tissue adaptation even without remodeling in the fracture lines. Davids followed seven patients with femoral rotations above 10 degrees for 1 year and noted that there was no significant improvement in femoral rotations at the end of 1 year. However, with the adaptation of soft tissues over time, he showed that rotational deformities up to 25 degrees were well tolerated and did not show clinical symptoms [13]. Keskin *et al* calculated

Table 1 Demographic datas and clinical features of the patients

		Number (%)
Gender		
Male	19	(82.6%)
Female	4	(17.4%)
Side		
Right	11	(47.8%)
Left	12	(52.2%)
	Mean	±SD
Age at the time of fracture (month)	32.9	±13.5
Radiological rotational measurement	27.2	±6.9
Clinical rotational measurement left	55.3	±9.4
Clinical rotational measurement right	54.6	±9.8
Clinical rotational measurement difference	3.0	±1.7
Left leg length (cm)	53.9	±7.1
Right leg length (cm)	53.8	±7.1
Leg length difference (cm)	0.3	±0.3
Follow-up (month)	31.9	±15.4

Table 2 Results of statistical analysis

	Radiological rotational measurement		Clinical rotational measurement		Leg length difference	
	R	*P*	*R*	*P*	*R*	*P*
Age at the time of fracture	−0.251	0.249	−0.075	0.733	0.745	0.175
Radiological rotational measurement			**0.634**	**0.001**	0.299	0.165
Clinical rotational measurement	**0.634**	**0.001**			−0.031	0.888
Leg length difference	0.299	0.165	−0.031	0.888		
Follow-up	0.061	0.784	0.025	0.909	−0.247	0.255

Pearson correlation analysis

the foot development angle of the patients after pediatric femur fractures, and according to the study, the change in the foot development angle was found to be significantly higher in those with a follow-up period of less than 1 year, those who underwent skeletal traction and those with the proximal fracture line and no complaints or clinical signs. These were observed in patients even with foot development angle differences up to 20 degrees [14]. In our study, no clinical findings or complaints related to trauma were encountered in all patients with an average follow-up of approximately 2.5 years. When the rotational differences measured by the clinical examination with the rotational measurements made on the radiograph after early casting were evaluated, it was observed that rotations measured radiologically at low degrees caused less clinical rotational difference. At the same time, it was observed that the average clinical rotational angle difference of three patients with a rotational deformity of 35 degrees and above, measured radiologically, decreased to a value of 5 degrees, and the patients tolerated even such high angles. As a study with similar results, Stephens *et al.* reported rotational deformity of up to 40 degrees in patients after casting, but they stated that none had any complaints [15]. After early closed reduction and spica casting, Stans *et al.* and Curtis *et al.* stated that rotations were detected at certain rates, but they did not cause clinical symptoms and did not cause complaints by the patients [16,17]. Similarly, in our study, the rotational deformities measured as 27.2 degrees on the radiographs taken after casting, decreased to an average of 3 degrees on clinical examination. However, there are also opinions arguing that rotational deformities remodel over time. Hägglund *et al.* have shown that the rotational deformities of pediatric femoral shaft fractures, which they followed for 10 years, can remodel over time [18].

The contribution of bone remodeling and soft tissue adaptation after a fracture could not be evaluated separately because the measurement we made during the patients' follow-up was not a radiological method but was based on clinical examination. Considering the previous studies, it was concluded that even if there was a limited bone remodeling, the patients did not show symptoms clinically and adapted to this situation with the effect of soft tissue adaptation. None of the patients had prolongation in the leg length on the fractured side than the healthy side, and the average leg length difference was found to be 3 mm in our clinical measurements; hence, no limping was found in any of the patients, and there was no need for insoles. These results showed us that early spica casting is an effective and well-tolerated method, and post-traction spica casting, which was much more common in the past, should not be used routinely.

In previous studies, computed tomography (CT) was mostly used to calculate postoperative rotational values [5,7]. Plánka *et al.* made rotational calculations with MRI because CT contains radiation [19]. Due to the cost of both methods and the radiation effect of CT, measurements were obtained on the basis of the calculations made on the direct graphy defined in the past; thus, additional imaging was not performed for the patients except for the radiographs taken during their routine controls, and unnecessary cost and radiation were avoided. Due to the easy accessibility of plain radiographs, being a simple method, and not requiring an additional examination for measurement due to its routine use in the first place in fracture follow-up, their use in the calculation of rotational measurements after pediatric bone fractures has become increasingly common in recent years. There are studies using direct roentgenograms to calculate rotational deformities after pediatric supracondylar humerus fractures and after pediatric distal radius fractures [20,21].

One of the most critical limitations of the method we used is that rotational calculation cannot be performed with some fracture types such as fractures without ends, which cannot be clearly selected on the X-ray, and fractures that do not have a fracture configuration to be used as landmarks in calculations. Radiological software should be sufficient to use this method effectively. Useful quality X-rays and systems capable of magnification are essential for accurate measurement; therefore, imaging systems with sufficient features were used in this study. Simultaneously, each patient's measurements separately by two different authors have enabled us to reduce the error margin. In the case of a difference between measurements of both surgeons, we aimed to reduce interobserver difference by defining the landmarks together as this measurement method has a mean absolute error for 3,97°, and this error is less for measurements under 30° [6]. Another limitation of our study is that residual rotational deformities were not calculated radiologically, because we did not use a radiological method while performing control measurements during follow-up. Because the study focused on clinical outcome, clinical angle measurements were preferred instead of radiological. Maximum sensitivity was shown in order not to cause any error in the measurements made with goniometer, but the foot porgression angle with gait analysis could not be applied due to clinical availability. The number of patients included in the study can also be shown as a limitation. Studies with more extended follow-up periods involving larger patient groups may contribute to more valid results.

As a result, pediatric femoral fractures are common traumas. In the treatment of these, early spica casting according to the patient's age is an effective method. Residual rotational deformities occur in certain degrees in the treatment of these fractures. The extent to which these deformities are remodeled during follow-up is still an ongoing discussion. The most important thing is the clinical effect of these deformities and their tolerance by the patients. It is seen that patients well tolerate such deformities even at high degrees. For these reasons, it was concluded that although the maximum attention was paid to fracture reduction quality during the first treatment, the rotational deformities that may occur would not cause clinical problems that would make post-treatment intervention essential, and that only the presence of fracture rotation was considered, patients did not need to perform postcast revisions or expensive and radiation-containing additional examinations but this conclusion is made for only patients under 5 years of age and deformities less than 30 degree, whereas mean age of our patients was 32.9 ± 13.5 months and mean deformity was 27.2 ± 6.9 degrees. A threshold value for maximum rotational deformity is yet to be found, and future studies with larger groups are needed for this parameter.

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Conflicts of interest

There are no conflicts of interest.

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