Comparison of Noncontact Plating with Conventional Methods and Osteosynthesis Techniques in the Treatment of Pediatric Femoral Fractures

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Abstract

Aim: Studies on surgical options in pediatric femoral fractures have been continuing for many years. We aimed to compare the noncontact plating we applied with the other techniques.

Methods: Pediatric patients treated for femoral shaft fracture were included. The patients were evaluated in terms of fracture type, time until surgery, duration of surgery, time of union, complications, Flynn criteria, radiological findings. 21 were in the elastic nailing (group 1), 27 were in the conventional plating (group 2), 11 were in the noncontact plating (group 3).

Results: The mean age was 8.3±1.4 (6-11) in group 1, 10.2±2.2 (7-15) in group 2, and 9.7±2.8 (7-15) in group 3. The time of union was 8.0±2.2 weeks (6-16) in group 1, 9.7±2.7 weeks (7-20) in group 2, and 7.1±1.0 weeks in group 3 (6 -9). In group 1, one patient had delayed union, two patients had a valgus deformity, two patients had minor wound site infection, and four patients had shortening of less than 2 cm. In group 2, three patients had a valgus deformity. Moreover, one patient underwent revision due to plate fracture. In group 3, no delayed union or deformity was observed in any patient.

Conclusions: The fact that elastic nailing, which is the most frequently recommended method in pediatric femoral fractures. However, it is obvious that conditions such as the absence of splinting, better reduction, fewer deformity, early rehabilitation provide advantages over noncontact plating. While it is up to the surgeon's preference, noncontact plating can be applied safely and successfully.

Keywords: *Pediatric femoral fracture, elastic nailing, locked plating, noncontact plating*

1. Introduction

While pediatric femoral fractures are less common than clavicle and wrist fractures, they are the most common orthopedic injury requiring hospitalization[1,2]. Conservative treatment, elastic nailing, and plate-screw applications are commonly used in pediatric femoral fractures. There are studies indicating that conservative treatment has successful outcomes up to sixty-six months[3]. However, patient care provided by the family, hygiene, difficulties during patient handling, and non-adoption of plaster cast are challenges of conservative treatment. Surgery comes to the forefront after six years of age[4]. In this case, elastic nailing, plate-screw systems, and external fixator fixation are used.

The use of external fixators is limited in open fractures due to pin tract infection and the difficulty of using extracorporeal implants. Elastic nailing and plate-screw systems are commonly used in closed fractures. There are many studies on these two techniques[5,6]. Noncontact plating, which is the subject of this study, is fracture fixation in such a way that the plate never contacts the bone. We think that it supports the callus formation since it does not exert pressure on the periosteum and allows micromovement. There are successful studies on the use of noncontact plating to treat open fractures and pathological fractures due to osteomyelitis[7-10]. However, we could not find a study comparing the mentioned technique with conventional methods in pediatric femoral fractures. There are scarce studies on this technique in the literature. We aimed to demonstrate the effect of this technique, which does not disturb the periosteal circulation, on pediatric femoral fractures.

2. Materials and methods

The study was initiated by obtaining approval from the Ethics Committee of our hospital (06/05/2021 no:1390). Patients aged between 6-18 years who were admitted to the emergency department of our hospital and diagnosed with femoral fractures between Janu-

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ary 2018 and June 2021 were screened retrospectively. One hundred fifty-five patients were reached. When patients who had multiple fractures, metabolic disease, tumor-related pathological fractures, and a follow-up period of less than six months and who underwent interlocking intramedullary nailing were excluded from the study, 59 patients were included in the study. The patients were divided into three groups, those who underwent elastic nailing (GROUP 1), those who underwent plate-screw osteosynthesis with a conventional method (GROUP 2), and those who underwent locking plate-screw osteosynthesis with a noncontact method (GROUP 3).

2.1. Surgical technique:

All patients were operated in the supine position under general anesthesia. In group 1, a closed reduction was initiated; however, when the reduction was prolonged, an open reduction was performed, and the surgery was completed with a standard retrograde technique with two nails. The long leg arched at the hip was splinted. In group 2, a closed reduction was performed. After the plate length was planned with fluoroscopy and shaped according to the bone anatomy, a 5-cm incision was made on the distal lateral of the femur, and the plate was advanced submuscularly. A 5-cm incision was made on the proximal part of the plate, and the plate was placed lateral to the closed reduced bone. It was fixed with locking and non-locking screws according to the surgeon's preference. In group 3, the plate was placed through a 5-cm incision in the lateral distal without shaping. Three mm osteotomes were placed between the plate and the bone proximally and distally, and screwing was started. The fracture position was fixed with locking screws so that the plate did not contact the bone in the reduction position we desired. Since we could not perform a very rigid fixation, we aimed to ensure that it would allow both micromovement and the callus formation under the plate. Splint fixation was not performed in group 2 and group 3. In group 1, the splint was terminated at the end of 45 days, and loading was initiated. In the other groups, partial loading was initiated when the callus tissue was observed in the control on day 20. All patients were called for control at weeks 3, 6, and 12 and at month 6.

The patients' age, sex, fracture type, time until surgery, duration of surgery, technique used, presence of complications, clinical and radiological findings (alignment, shortness, callus), and Flynn criteria[11] were recorded. These results were evaluated statistically.

2.2 Statistical Analysis:

SPSS 23.0 package program was used for the statistical analysis of the data. Categorical measurements were summarized as numbers and percentages, while continuous measurements were summarized as mean and standard deviation (median and minimum-maximum values where appropriate). The Shapiro-Wilk test was used to determine whether the parameters in the study were normally distributed. The Kruskal-Wallis test was used for non-normally distributed parameters. The post hoc Bonferroni method was used to examine the source of differences between the groups. The level of statistical significance was accepted as $p<0.05$ in all tests.

3. Results

As a result of the retrospective evaluation, 59 patients were included in the study. There were 21 patients in group 1, 27 patients in group 2, and 11 patients in group 3. Age, time until surgery, duration of surgery, time of union values, and the statistical comparison of these values are presented in Table 1. The sex distribution of the patients by groups, their fracture types, and the callus pattern of the union tissue are shown in Table 2.

Table 1

Comparison of age, time until surgery, duration of surgery, and time of union

	Group 1 (n=21) Mean±sd Med (Min-Max)	Group 2 (n=27) Mean±sd Med (Min-Max)	Group 3 (n=11) Mean±sd Med (Min-Max)	p1	p2
Age (years)	8.3±1.4 8 (6-11)	10.2±2.2 10 (7-15)	9.7±2.8 9 (7-15)	0.013*	Group2-1; p=0.007
Time until surgery (hours)	9.2±4.6 8 (4-24)	9.0±4.6 8 (4-24)	7.6±1.2 8 (6-10)	0.695	
Duration of surgery (min)	39.8±4.2 40 (30-48)	54.4±10.5 54 (38-98)	47.1±6.4 45 (40-60)	<0.001**	Group2-1; p<0.001 Group2-3; p=0.042
Time of union (weeks)	8.0±2.2 8 (6-16)	9.7±2.7 9 (7-20)	7.1±1.0 7 (6-9)	<0.001**	Group2-1; p=0.044 Group2-3; p=0.007

* p<0.05, **p<0.001, p1: Kruskal-Wallis test, p2: Post hoc Bonferroni test

Table 2

Sex, fracture type, callus pattern

	Sex F/M	Transverse fracture	Oblique fracture	Spiral fracture	Primary callus	Secondary callus
Group 1	8/13	13	3	5	0	21
Group 2	4/23	14	2	11	23	4
Group 3	2/9	5	3	3	0	11

Table 3

Evaluation of the groups according to the Flynn criteria

	Excellent	Good	Poor
Group 1	15	5	1
Group 2	17	8	2
Group 3	9	2	0

With regard to complications, two patients (10 and 17 degrees) in group 1 had union in the valgus. Two patients had minor wound site infection, and four patients had shortening of less than 2 cm; however, it did not affect their gait. In group 2, one patient underwent revision with a plate due to plate fracture in the second month, and three patients (11, 12, and 8 degrees) had union in the valgus. While four patients had minor wound site infection, there was no shortness in any of the patients. In group 3, two patients had minor wound site infection, while no shortening or deformity was present in any of the patients. Upon examining the Flynn criteria, in group 1, the excellent result was 15, the good result was 5, and the poor result was 1. In group 2, the excellent result was 17, the good result was 8, and the poor result was 2. In group 3, the excellent result was 9, the good result was 2, and the poor result was 0 (Table 3).

A significant difference ($p<0.05$) was found between the groups with the duration of surgery ($p<0.001$) and time of union ($p<0.001$) results of the patients. When the source of difference between the groups was examined, it was determined that the difference originated from the significantly longer duration of surgery and time of union of the patients in group 2 compared to the patients in group 1 and group 3 ($p<0.05$) (table 1), which revealed that the duration of

surgery and time of union in group 2 were significantly longer than the other groups.

It was found that the reason for the difference determined between the groups with the age results (p=0.013) was the higher mean age of the patients in group 2 compared to the patients in group 1 (p<0.05).

4. Discussion

The most significant strength of our study is the comparison of the noncontact plating technique with two known surgical techniques in pediatric femoral fractures. Casting, external fixation, elastic nailing, and plate-screw systems are used to treat femoral shaft fractures in children. There is no absolute consensus on these techniques among the authors. However, the North American Pediatric Orthopedic Society argues that surgical treatment should be performed after the age of six[12].

Nowadays, elastic nailing is one of the most commonly used methods. In the studies, successful outcomes of elastic nailing and rotational stability problems in transverse or comminuted fractures were observed[13,14]. Furthermore, the fact that unstable fractures such as spiral and comminuted fractures are not supported by splint fixation may lead to the development of shortening[14]. Although we used postoperative splints for all patients, we observed complications of shortening and union in the valgus in elastic nailing, similar to the literature. Nevertheless, noncontact with the periosteum in elastic nailing appears as a significant and obvious advantage over the plate-screw system. The external fixator fixation also has the same advantage. However, external fixators are not frequently preferred in closed fractures due to frequent complications such as patient compliance and pin tract problems[15,16]. In this case, while noncontact plating has advantages by working with the logic of an external fixator, it does not have the complications of an external fixator due to the absence of implants outside the skin. In our study, while there were patients who recovered with valgus deformity in groups 1-2, this deformity was not observed in group 3.

The closed reduction of the fracture line is also important for the preservation of the fracture hematoma. The closed reduction was planned in all three groups, and the case was started. However, the open reduction was performed in four patients with transverse fractures in group 1. In group 2 and group 3, the closed reduction was applied in all cases. The fact that closed reduction is attempted and open reduction is initiated in elastic nailing is also encountered in the literature. A study by Heffernan et al. emphasized that open reduction should be initiated in case of prolonged closed reduction in elastic nailing in pediatric femoral fractures. The researchers reported that they had difficulty in reduction, especially in overweight and elderly patients[17].

With the understanding of the importance of periosteal circulation in fracture union, the plates used were changed so that they would not prevent biological osteosynthesis. Instead of flat plates, LC-DCP (limited contact plate), point contact plates were produced[18,19]. The aim here is both the non-disturbance of the periosteal circulation and the advancement of callus tissue through spaces. We think that the noncontact of the plate placed as in group 3 with the bone will further contribute to biological recovery. The shorter time of union than in the conventional plating technique supports our opinion.

In group 1 and group 3, micromovement caused the callus tissue to be in the form of secondary osteosynthesis; however, the fact that the implants did not fully contact the periosteum paved the way for the placement of the callus tissue under the plate.

The positive effect of micromovement on union was also demonstrated by Ilizarov's studies conducted with external fixators. Successful outcomes were obtained in the treatment of fractures with an external fixator, and it was revealed that rigid fixation was not necessary in osteosynthesis[20]. Therefore, indirect (secondary) bone healing occurred in fixation, allowing micromovement obtained with nails and external fixators. Indirect bone healing is healing with apparent callus tissue, as in natural fracture healing. It has been known for a long time that micromovement in the fracture line increases callus formation[21]. In our study, we attributed the apparent callus appearance on x-rays to this micromovement, even in the 3rd-week controls (Figure 1). Furthermore, with the 3 mm osteotome we placed under the plate, we allowed the callus tissue to fill under the plate during the union period. No need for splinting provides comfort to the patient and convenience in rehabilitation.

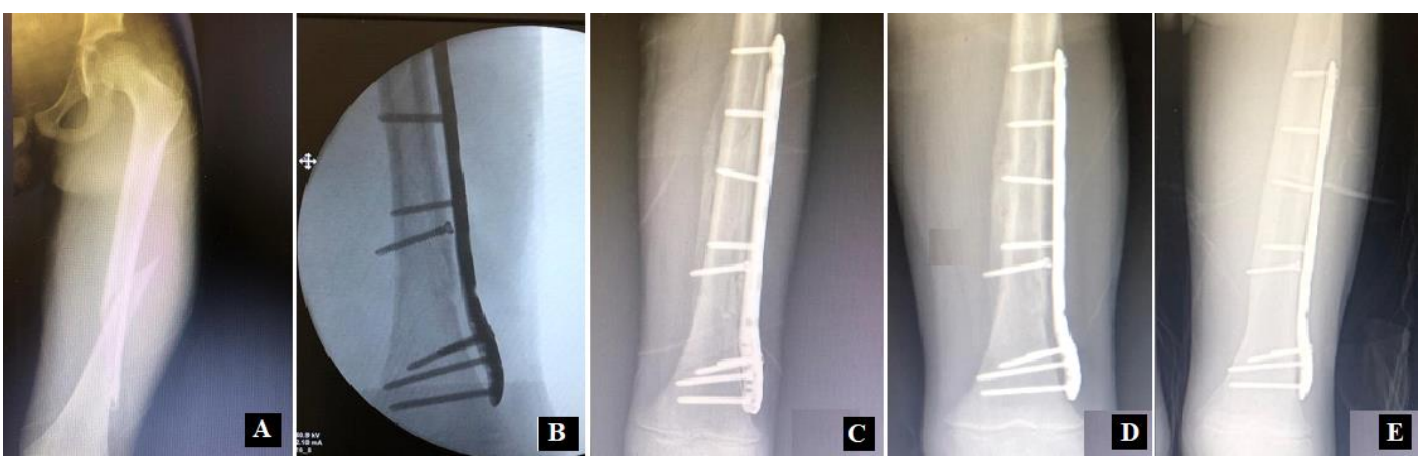

Figure 1

A) preoperative X-ray **B)** intraoperative X-ray **C)** postoperative 3. week X-ray **D)** postoperative 6. week X-ray **E)** postoperative 6. month X-ray

Figure 2

Group 1 A) preoperative X-ray **B)** postoperative 1.day X-Ray **C)** postoperative 6. week X-Ray **C)** postoperative 6. month X-Ray

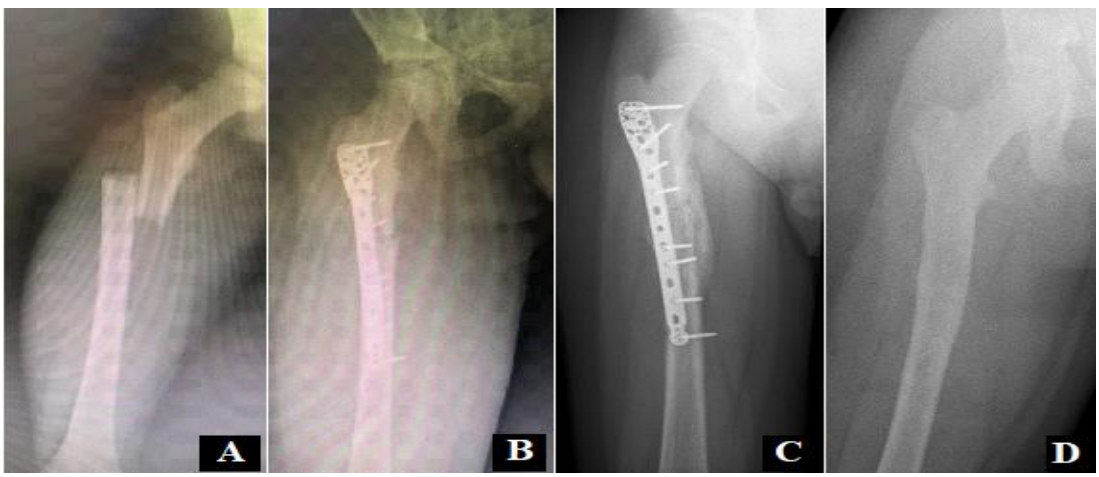

Figure 3

Group 2 A) preoperative X-Ray **B)** postoperative 1. day X-Ray **C)** postoperative 6. week X-Ray **D)** 1. year X-Ray

There are many studies reporting successful outcomes with elastic nailing in pediatric femoral fractures without causing a significant deformity[14,22]. Nevertheless, in a study conducted by Heybeli et al. in 2004 and evaluating the application of titanium elastic nails in femoral fractures, the researchers revealed that this technique was effective in a wide range of age groups, such as 5-15 years, and checked deformity with tomography. Rotation, which appeared normal on X-ray, was found to be significantly retroverted compared to the intact side on tomography[14]. We agree with the authors who reported poor outcomes in terms of loss of compliance and delayed union in patients over 49 kg and in comminuted fractures[23]. Furthermore, a study conducted in the 11-15 age group reported that plate-screw osteosynthesis should be considered an effective method due to stable and complete anatomical fixation[24].

When the time of union was evaluated, while no significant difference was found between group 1 and group 3, it was found to be significantly longer in group 2 compared to the other two groups. However, dense callus tissue due to secondary osteosynthesis, which was significantly observed in group 3, provides confidence in early rehabilitation and mobilization (Figure 1).

Although the intraoperative reduction is excellent in fixation with elastic nails, deterioration may occur in the follow-ups. In our study, the only case in group 1 who caused a poor outcome according to the Flynn criteria was completely reduced on the first postoperative x-ray and recovered in a 17-degree valgus in the final control (Figure 2). This patient was an 11-year-old male patient. In this technique, the compliance of the patient and the patient's relatives is very important. In this case, we estimated that reduction was impaired by the weight of the leg and the splint during the patient's transfer at home. According to the literature review, Anderson et al. should have suspected that rotation was impaired in the postoperative period. Therefore, they reported that the deformity defect could be prevented by applying an external fixator on the elastic nail[25]. While elastic nailing is the first choice in pediatric femoral shaft fractures, we recommend noncontact plating, especially in well-built patients over the age of 10.

Recovery with secondary callus tissue in groups 1 and 3 gave confidence to the surgeon in the follow-ups. The dense callus tissue, which is formed earlier, shares the load on the implant earlier. Here, the importance of micromovement emerges. We would like to mention a situation that caught our attention during the review. In group 2, while primary union was observed in two patients for whom two interfragmentary screws were used in spiral fractures with bridge plating, union with secondary callus was observed in patients for whom no interfragmentary screw was used or a single screw was used. While an interfragmentary single screw did not prevent micromovement, two screws may have prevented micromovement by causing more rigid fixation, which needs to be studied.

In group 2, the plate was tilted outside and placed inside. We observed that the attachment of the plate to the bone with non-locking screws during fracture fixation impaired reduction in three patients. An error that can be made while shaping the plate outside impairs the reduction with non-locking screws (Figure 3). In the noncontact plating that we recommend, the shape of the plate is unimportant after the reduction is achieved. The fracture is fixed with a locking plate that does not contact the bone in the reduced position.

The authors are aware of the study's limitations. Firstly, the study was conducted as retrospective. Secondly, although we used standard 3 mm for noncontact plating in our study, there is a need for future biomechanical studies for optimal distance. Finally, since noncontact plating is a new subject, it would be appropriate to increase the number of cases and conduct larger series of investigations.

5. Conclusions

In conclusion, the fact that elastic nailing, the most frequently recommended method in pediatric femoral fractures, is a less invasive method is still considered an advantage compared to noncontact plating. However, it is obvious that conditions such as the absence of splinting, better reduction, fewer deformity complications, early mobilization and rehabilitation provide advantages over noncontact plating. Based on this information, while it is up to the surgeon's preference, noncontact plating can be applied safely and successfully in appropriate patients.

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Statement of ethics

This study was approved from Adana City Training and Research Hospital Ethics Committee (Dated: 2021-80/380). Informed consent was taken from all patients.

Conflict of interest statement

The authors declare that they have no financial conflict of interest with regard to the content of this report.

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Author contributions

All authors conceptualization, design, supervision, literature review, conduction and writing- original draft preparation. All authors read and approved the final manuscript.

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