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Adult Proximal Humeral Locking Plate Is a Good Alternative Option in the Treatment of Adolescent Subtrochanteric Femur Fractures: A Case Series and Literature Review

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Purpose: Management of pediatric subtrochanteric femur fractures (SFFs) is difficult. The aim of this study was to evaluate the outcomes of adolescent SFFs treated with adult proximal humeral locking plates (PHLPs).
Materials and Methods: A retrospective analysis of 18 adolescents (11 male, 7 female) with a diagnosis of SFF who underwent internal fixation with a PHLP was conducted. Data regarding injury mechanism, fracture pattern, and time to union were recorded for all patients. In addition, a clinical and functional evaluation of patients was performed using the Harris hip score (HHS), Iowa hip score (IHS), modified Merle d'Aubigne-Postel score (MMAPS), Flynn criteria, and hip range of motion (ROM).
Results: The mean age of the patients was 12.72±2.05 years (range, 10-16 years). Radiological observation was performed for evaluation of five different injury mechanisms and different fracture patterns in patients. The mean postoperative HHS was 92.27±5.61, the mean IHS was 90.88±6.46, and the mean MMAPS was 17.22±0.94. According to the Flynn criteria, excellent results were achieved in 14 cases and satisfactory results were obtained in four cases. Measurements of the patients' mean hip ROM values were as follows: 17.77±3.52° in extension, 115.27±6.74° in flexion, 43.05±3.48° in abduction, 27.50±4.28° in adduction, 42.22±4.60° in internal rotation, and 42.22±3.91° in external rotation.
Conclusion: Surgery performed on adolescent patients using an adult PHLP showed good, safe results. Therefore, it should be considered as an alternative option.

Key Words: Femoral fractures, Adolescent trauma, Hip joint, Fracture fixation, Internal fixators

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INTRODUCTION

Pediatric subtrochanteric femur fractures (SFFs), which are relatively rare, account for 4-10% of all femur fractures and occur more commonly in male patients[1]. SFFs are usually the result of a high-energy injury[2]. Because strong displacement of the proximal part by the flexor, abductor, and external rotator muscles tends to occur, these fractures are unstable, especially in adolescents (10-19 years)[3].

Many different methods for treatment of SFFs have been described, including titanium elastic nails (TENs), antegrade intramedullary nailing (IMN), traction and hip spica casting, open plating, submuscular plating, and external fixators[4-9]. The patient's age is an important factor in determining the method of treatment for adolescent SFFs. Although traction and hip spica casting are generally regarded as appropriate for use in the treatment of younger patients, most authors recommend open reduction and internal fixation, especially in patients older than 10 years[10,11]. Both conservative and surgical treatment have shown a high rate of success and malunion and nonunion have rarely been reported[12].

The popularity of plating in the treatment of these fractures has increased due to the high complication rates associated with TENs in the surgical treatment of adolescent SFFs[2,13,14]. Pediatric hip locking plates are generally not long enough for use in treatment of these fractures, thus there is a need for alternative plates[15]. Alternatives include reconstruction plates, dynamic compression plates, and adult distal/proximal tibial locking plates. Use of proximal humeral locking plates (PHLPs), which are designed primarily for the treatment of proximal humeral fractures in adults, in the fixation of pediatric SFFs has recently been reported[15]. Use of a PHLP enables multi-directional screwing to the proximal part and it is a low-profile plate[16].

The aim of this study was to evaluate the clinical, radiological, and functional outcomes of treatment using adult PHLP in adolescent patients with SFF. According to our hypothesis, PHLPs may be an alternative option in the treatment of adolescent SFF.

MATERIALS AND METHODS

1. Patient Selection

The study was approved by institutional Review Board of Ankara City Hospital (approval No. E1-21-2250) and writ-

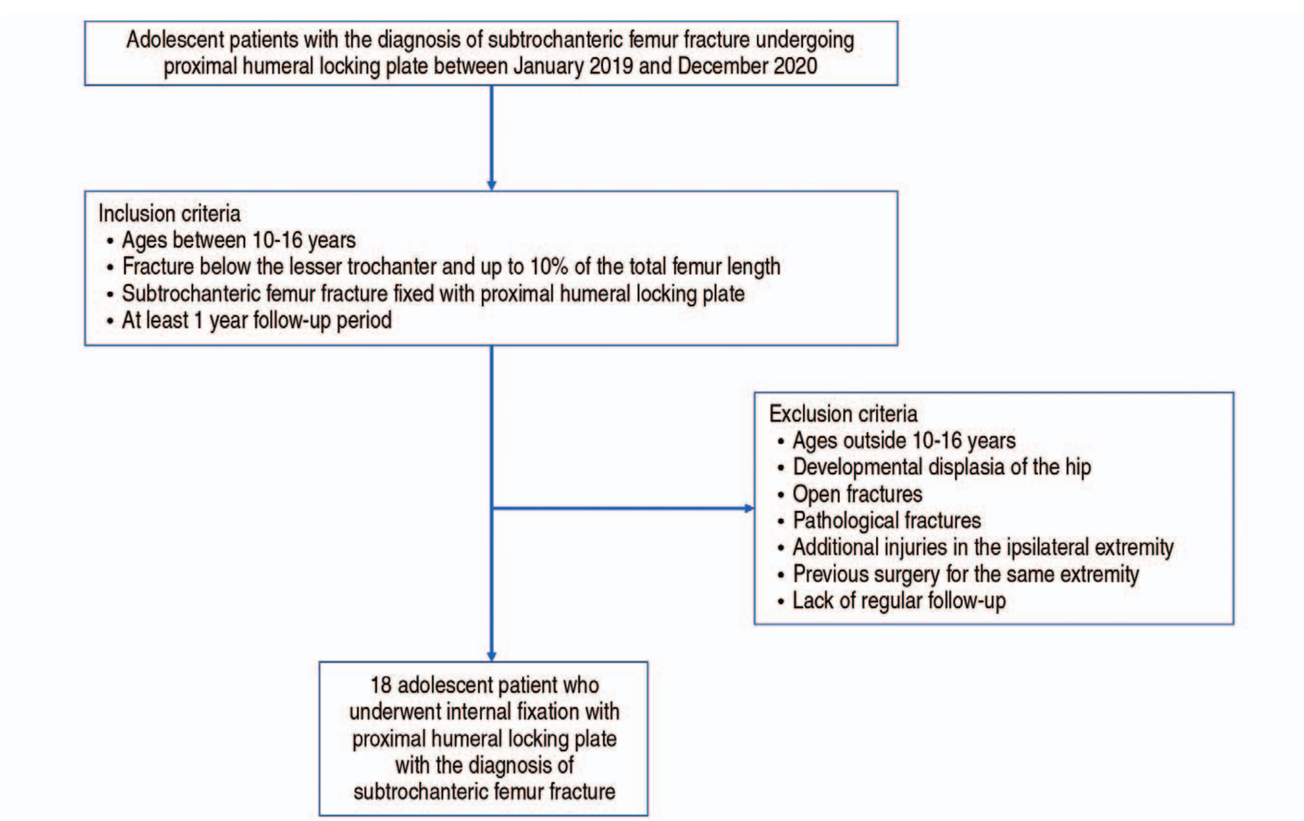

Fig. 1. The flow chart for the study.

ten informed consent was provided by the parents of all children prior to the commencement of the study. A retrospective analysis of adolescent patients who presented at Ankara City Hospital with the diagnosis of SFF between January 2019 and December 2020 and who underwent treatment with a PHLP was conducted. Fractures below the lesser trochanter and up to 10% of the total length of the femur were regarded as SFFs[17]. Inclusion and exclusion criteria are shown in Fig. 1.

2. Surgical Procedure

The surgical procedure was performed on all patients in the supine position under general anesthesia. All surgeries were performed by one senior surgeon. Surgery performed using a lateral approach to the thigh was preferred. The skin incision was made starting from the greater trochanter according to the fracture level and the length of the plate to be placed. The vastus lateralis muscle was cut in an L shape from its posterior part and tilted anteriorly for exposure of the femur and fracture line. Following reduction of the fracture, a plate of suitable size for the fracture level was selected. In order to achieve stable fixation, at least two rows of locking screws with the longest possible screws were placed on the proximal part of the fracture with placement of 4-5 cortex screws on the distal fracture part (Fig. 2). After reduction was achieved for long spiral fractures, one or two polyethylene cerclage tapes were applied for stabilization of the fracture. First, compression of the plate to the bone was performed using a cortical screw. Optimally sized locking screws were then used to complete the fracture fixation (Fig. 3). In comminuted fractures, fixation was performed with bridge plating after achievement of anatomical alignment (Fig. 4). The main advantages of the PHLP are that different lengths can be used, it is a low-profile plate, and it enables insertion of many and multidirectional screws. After the fixation was completed, the hip range of motion (ROM) was examined and fluoroscopic examination was performed for evaluation of stability. The operation was then concluded.

Fig. 2. Side (A) and front (B) view of the proximal humeral locking plate used for fixation of a subtrochanteric femur fracture. Note the placement of numerous and multi-directional screws from the proximal part of the plate.

3. Rehabilitation

All patients began passive and active knee and hip ROM exercises immediately after surgery. The patients performed non-weight-bearing activities on the first postoperative day. In accordance with radiographic and clinical assessments, all patients performed partial weight-bearing activities after 3-4 weeks and full weight-bearing activities at 6-8 weeks after surgery.

4. Clinic and Radiographic Assessments

Demographic information, the mechanism of injury, fracture pattern, and mean follow-up duration were recorded for all patients. The radiographic union time was determined using anteroposterior and lateral femoral radiographs taken during the clinical follow-up. Criteria for fracture union included no pain/tenderness during palpation of the fracture line or weight-bearing and bridging of the fracture by a callus, trabeculae, or bone[18]. In addition, clinical and functional evaluation of all patients was performed in the first year after surgery using a goniometer according to hip ROM, Harris hip score (HHS), Iowa hip score (IHS), modified Merle d'Aubigne-Postel score (MMAPS), and Flynn criteria[14,19-21]. Regarding the HHS and IHS, scores of 90-100 are considered excellent, 80-89 good, 70-79 fair, and <70 poor, while for the MMAPS, scores of 17-18 are excellent, 12-16 good, 6-11 fair, and <6 unsatisfactory[22-24]. Additional surgical procedures and complications, if any, were also noted. Statistical analysis was performed using IBM SPSS Statistics

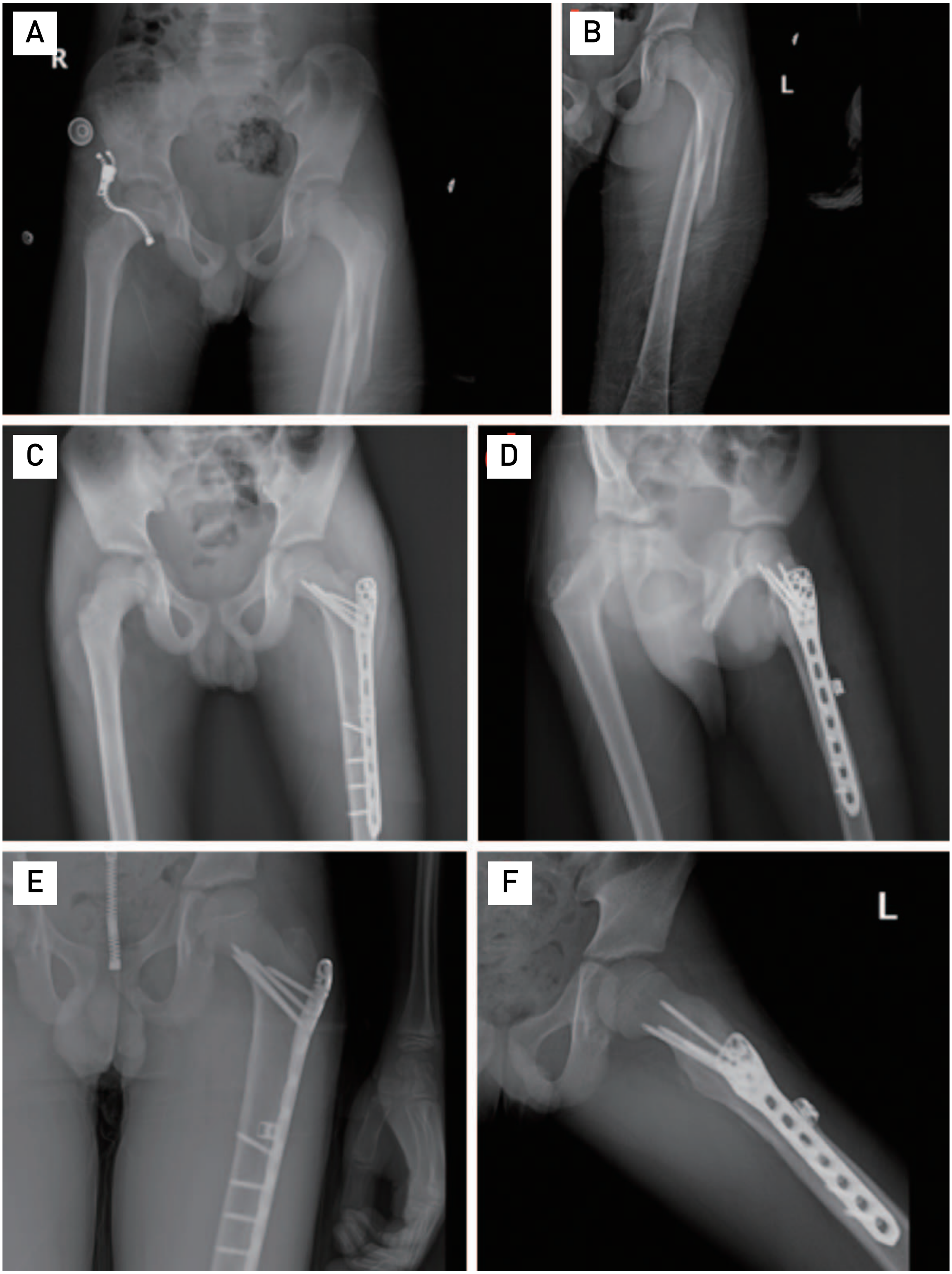

Fig. 3. Subtrochanteric femur fracture detected in the anteroposterior (AP) pelvis (A) and left femur (B) radiographs of a 10-year-old male patient who presented at our clinic after an in-vehicle traffic accident. After open reduction, one polyethylene cerclage tape was applied first for fixation of the fracture line. Postoperative AP (C) and lateral femur (D) radiographs of the patient, in whom fracture fixation was completed with a proximal humeral locking plate, were obtained. AP (E) and lateral (F) femur radiographs taken at the eighth postoperative week show complete union of the fracture line and the patient was able to walk with full weight-bearing without pain.

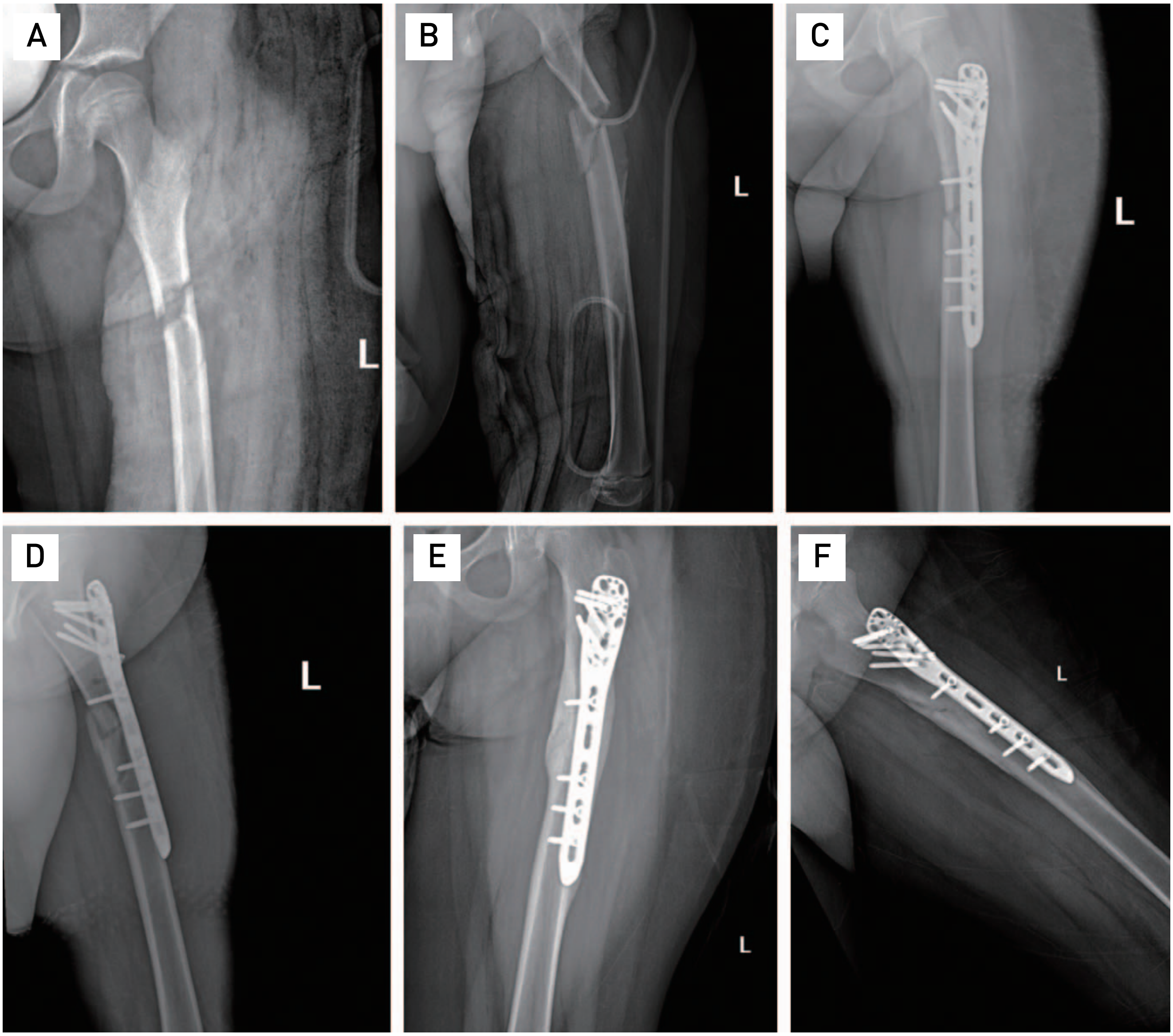

Fig. 4. Subtrochanteric femur fracture with butterfly fragment observed in the anteroposterior (AP) (A) and lateral (B) femur radiographs of a 12-year-old female patient who presented at our clinic after a non-vehicle traffic accident. Bridge plating was performed to the subtrochanteric femur fracture with butterfly fragment after reduction. Due to the fracture pattern, the plate was placed more posteriorly and the AP (C) and lateral (D) radiographs of the fixation with the proximal humeral locking plate. As shown on AP (E) and lateral (F) femur radiographs taken at the ninth postoperative week, complete healing of the fracture line was achieved with formation of a callus and the patient was able to walk with full weight-bearing without pain.

for Windows (ver. 24.0; IBM, Armonk, NY, USA).

RESULTS

Information regarding patient demographics, fracture union rates and follow-up times, joint ROM values, and functional scores are shown in Table 1. An evaluation of 18 adolescents (11 male, 7 female; mean age, 12.72±2.05 years; range, 10-16 years) was conducted in this study.

Most injury mechanisms are a result of high energy trauma such as in-vehicle or non-vehicle traffic accidents and falls from heights. Fracture patterns range from simple transverse fracture to comminuted fracture. The mean time to union was 9.94±1.62 weeks and union was achieved in all cases; there were no cases of nonunion. The mean follow-up period was 25.11±5.89 months.

The mean degrees for hip ROM were 17.77±3.52° in extension, 115.27±6.74° in flexion, 43.05±3.48° in abduc-

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Table 1. Demographic Characteristics and Clinical, Functional, and Radiological Outcomes of Patients

Patient No.	Age (yr)	Sex	Injury mechanism	Fracture pattern	Time to union (wk)	Follow-up time (mo)	Hip ROM (°)			Harris hip score	Iowa hip score	Modified Merle d'Aubigne-Postel score	Flynn criteria
							E-F	AB-AD	IR-ER				
1	13	M	In-vehicle traffic accident	Short oblique	10	35	20-120	45-30	45-45	100	100	18	Excellent
2	10	M	Fall from a height	Long spiral	8	33	15-110	45-30	40-40	92	90	17	Excellent
3	12	F	Non-vehicle traffic accident	Butterfly fragment	9	32	15-120	45-30	45-45	94	93	17	Excellent
4	11	F	Simple fall	Transverse	11	31	20-120	45-30	45-45	98	94	18	Excellent
5	10	M	In-vehicle traffic accident	Long spiral	8	28	20-105	40-25	35-40	88	89	17	Excellent
6	12	M	Fall from a height	Long spiral	10	28	10-110	40-20	35-35	86	84	16	Satisfactory
7	15	F	Non-vehicle traffic accident	Butterfly fragment	11	27	10-100	35-20	30-35	82	78	15	Satisfactory
8	10	M	Simple fall	Short oblique	8	26	20-120	45-30	45-45	92	93	18	Excellent
9	15	F	In-vehicle traffic accident	Transverse	12	26	20-120	45-30	45-45	100	100	18	Excellent
10	12	M	Non-vehicle traffic accident	Long spiral	10	25	15-120	45-30	45-40	90	87	18	Excellent
11	13	M	Non-vehicle traffic accident	Short oblique	9	24	20-120	40-30	45-45	100	100	18	Excellent
12	14	F	Bicycle accident	Transverse	11	24	20-120	45-30	45-45	86	82	17	Excellent
13	16	M	Simple fall	Short oblique	12	23	20-120	45-30	45-45	97	96	18	Excellent
14	11	M	Fall from a height	Transverse	7	22	20-120	45-30	45-45	90	91	18	Excellent
15	16	F	In-vehicle traffic accident	Comminuted	13	21	20-105	35-20	40-35	84	82	16	Satisfactory
16	13	M	Bicycle accident	Short oblique	9	19	20-120	45-30	45-45	94	95	17	Excellent
17	11	M	Fall from a height	Long spiral	10	16	20-110	45-20	40-40	96	93	18	Excellent
18	15	F	In-vehicle traffic accident	Short oblique	11	12	15-115	45-30	45-45	92	89	16	Satisfactory

M: male, F: female, ROM: range of motion, E: extension, F: flexion, AB: abduction, AD: adduction, IR: internal rotation, ER: external rotation.

tion, 27.50±4.28° in adduction, 42.22±4.60° in internal rotation, and 42.22±3.91° in external rotation.

Functional evaluation of the patients was performed using four different scoring systems. The mean HHS was 92.27 ±5.61; excellent results were obtained for 13 patients and good results were obtained for five patients. The mean IHS was 90.88±6.46, with excellent results for 11 patients, good results for six patients, and fair results for one patient. The mean MMAPS was calculated as 17.22±0.94, with excellent results for 14 patients and good results for four patients. Finally, according to evaluation using the Flynn criteria, 14 excellent and four satisfactory results were obtained for these patients.

Union was achieved in all cases and none of the patients underwent revision surgery for nonunion or malunion. Implant removal was performed in one case due to plate irritation at the beginning of the second year after surgery. There were no other complications and no additional procedures were performed.

DISCUSSION

The principle finding of this study is that the results of surgery performed on adolescent patients using adult PHLP showed complete union, no complications, and good clinical and functional recovery in all cases.

SFFs occurring in the pediatric population are complex and treatment can be challenging for orthopedic surgeons[25,26]. There is no consensus among authors with regard to conservative and surgical treatments. As suggested by Schwarz et al.[11], in pediatric cases of SFFs, conservative treatment should be tried first and application of osteosynthesis with a dynamic compression plate should be performed in cases where successful reduction could not be achieved with traction alone. According to Ireland and Fisher[25], use of traction and hip spica casting would be appropriate for children younger than 10 years of age and surgery would be necessary only in cases where acceptable reduction could not be obtained in children older than 10 years. By contrast, a retrospective study conducted by Jarvis et al.[27] which included 13 patients who underwent treatment for SFFs, reported that satisfactory results were obtained for 8 of 10 patients who underwent surgical treatment, while severe malalignment and leg length discrepancy (LLD) were reported in three patients who received conservative treatment. Li et al.[2] also placed emphasis on surgical treatment in order to achieve early mobilization and to minimize the risk of complication. The importance of surgical treatment has increased in recent years due to the wide range of fixation methods and the potential for achieving early mobilization. SFFs are considered unstable; therefore, surgical treatment is essential, particularly in adolescents.

Many types of implants, including TENs, antegrade IMN, condylar blade plates, and reconstruction plates, are used for the fixation of pediatric SFFs. Studies have demonstrated the safety and effectiveness of TEN for treatment of displaced fractures of the femoral shaft in children aged 6-12 years and weighing less than 50 kg (110 lb); however, its use is controversial in children older than those in this age range and weight, and in SFFs[28-30]. In addition, due to loss of reduction in adolescents, it can lead to development of LLD, malalignment, and sagittal plane angulation[31]. Anterograde IMN is an important treatment option, particularly for fractures of the subtrochanteric femur and the femoral shaft in adults; however, it is not favored in pediatric SFFs due to the risks of trochanteric fracture, lateral cortex fracture, avascular necrosis of the femoral head, proximal femoral valgus deformity, femoral neck narrowing and arrest in the growth plate of the greater trochanter[32-37]. A study conducted by Herrera-Soto et al.[38] reported on performance of statically locked IMN in 10 pediatric patients with SFFs with a mean age of 12 years; lengthening of the affected extremity was reported in two patients and heterotopic ossification was reported in two patients. A retrospective evaluation of 54 patients aged 5-12 years with the diagnosis of SFF who underwent surgery using TENs or plate fixation conducted by Li et al.[2] reported better results and lower complication rates in the plate fixation group. According to El-Sayed et al.[39], who followed 18 patients who underwent SFF fixation using a 4.5-mm contoured reconstruction plate for an average of 38 months, union was achieved within a mean period of eight weeks, all in anatomical alignment, and none of the patients developed LLD. Sanders and Egol[40] reported on treatment of two patients with pediatric SFFs using a distal tibial locking plate in one case and a proximal tibial locking plate in the other; satisfactory results were achieved in both cases. Plate osteosynthesis is regarded as a safe and effective method for achievement of anatomical alignment and stable fixation in the treatment of these fractures. However, due to the insufficient length of the existing pediatric proximal femoral locking plates, we were determined to find alternative implants.

Reports on the use of PHLPs in the fixation of pediatric SFFs, as in the current study, have become increasingly common in the literature. Newbury et al.[41], who reported on application of a PHLP in the treatment of a 14-year-old patient who developed a pathological SFF resulting from an aneurysmal bone cyst, achieved complete union with a two-year follow-up period. Cortes et al.[12] reported on application of a PHLP in the revision surgery of an 11-year-old patient who had previously undergone treatment with a pediatric proximal femur locking plate, which resulted in nonunion. Adequate healing of the fracture was subsequently achieved at the end of the sixth month. In another study, excision of an osteoid osteoma and prophylactic fixation with PHILOS® plates were performed in two patients for treatment of an osteoid osteoma of the calcar femorale[42]. The only case series found in the literature regarding the treatment of pediatric SFFs with adult PHLPs was reported by Gogna et al.[15]; eight patients were followed for a mean period of 32 months, the mean time to union was 8.75 weeks, and the mean HHS was 80.25. The results demonstrated that PHLPs were a good treatment option in the surgical treatment of SFFs in patients aged 10-16 years[15]. The current study is the largest case series included in the literature evaluating the role of PHLPs in the treatment of adolescent SFFs. The follow-up period was at least one year for all patients, and the mean follow-up period was more than two years. In our study, functional evaluation of patients was performed using four different scoring systems, the HHS, IHS, MMAPS, and Flynn criteria, and the results for each patient were provided separately for each scoring system. In addition, meticulous measurement of all hip ROM values was performed for each patient and more quantitative data were presented. Although our case series is not large, declaration of maximum clinical and functional outcomes is based on the existing cases.

TENs may not provide stable fixation, particularly in cases of long spiral and comminuted fractures. The risk of malalignment and LLD can be minimized in these types of fractures by treatment with either interfragmentary compression or a bridging plate method according to the fracture pattern[2]. When use of conventional reconstruction plates and dynamic compression plates is preferred, placement of a sufficient number of screws on the proximal part of the fracture is not possible and the screws that are placed are not suitable for the collodiaphyseal angle. PHLPs, which we preferred in our case series, offer a number of advantages. First, among the available locking plates, a PHLP is a low-profile locking plate and most suitable for the anatomy of the pediatric proximal femur. Using this plate, the longest possible locking screws can be placed in at least two rows on the proximal part of the fracture, creating a stronger fixation than that achieved with use of other conventional plates. In addition, the possibility of implant failure is reduced due to the multi-directionality of screws at the proximal part of the fracture. Union was achieved in all patients in our case series, and this theory is supported by the absence of malunion or nonunion.

This study has some limitations. First, it was a retrospective study, and data for the patients before surgery was not available. Second, we included only one group with no control group. Third, the number of patients was small and the follow-up period was brief. Fourth, although all scoring was performed by the same person, these scores are often based on patient self-reports and can therefore be subjective. Finally, although extreme care was used in measurements of joint ROM, intraobserver error is possible.

CONCLUSION

Surgery performed on adolescent patients using an adult PHLP showed good, safe results. Therefore, its use should be considered as an alternative option.

CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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