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Adult proximal humerus locking plate for fixation of paediatric intertrochanteric femoral fractures

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ABSTRACT

Aims: There are multiple fixation methods for the surgical treatment of intertrochanteric femur fractures in children and adolescents, but there is still no consensus on the optimal implant. Recently, adult proximal humeral locking plates have been advocated for the fixation of these fractures; however, insufficient data is available for their efficacy. This retrospective study evaluated the radiological and clinical outcomes of pediatric intertrochanteric fractures treated with adult humerus proximal plates.

Methods: This was a single-center, retrospective study that included children aged between 11 and 16 years who underwent surgery for intertrochanteric hip fractures using adult proximal humeral locking plates between January 2012 and January 2019. The exclusion criteria were nondisplaced fractures, concomitant musculoskeletal and other system injuries, pathological fractures, and a history of previous surgery on the same hip or femur. The duration of fracture union was evaluated in the follow-up radiographs. Clinical outcomes were evaluated using the Harris hip score (HHS) and Ratliff criteria. All complications during the follow-up were recorded.

Results: The study included 24 children (15 males, nine females) with a mean age of 12.6±1.4 years (11 to 15 years). The mean follow-up time was 34±9.4 months (22 to 60 months). The mean fracture union time was 12.8±2.2 weeks (10 to 16 weeks). The HHS was 92±1.9 (89 to 95) at the final follow-up. All patients were rated good according to the Ratliff criteria. None of the patients had avascular necrosis of the femoral head, nonunion, malunion, limb-length discrepancy, or implant failure at the final follow-up. No patient required revision surgery.

Conclusions: The findings of this study showed that the fixation of pediatric intertrochanteric fractures with adult humerus proximal plates is a successful fixation option that provides good clinical outcomes based on the HHS and Ratliff criteria, and excellent radiological outcome with a high rate of fracture union, with low complication rates.

Introduction

Hip fractures in children are rare compared with adults. They comprise less than one percent of all pediatric fractures (1-4). Moreover, the prevalence in children is less than one percent of the prevalence in adults (3). The incidence is highest in children above 11 years of age (1). Pediatric hip fractures typically result from high-energy trauma, such as a motor vehicle accident or a fall from height (5-7). Standard radiographs are generally sufficient for diagnosis (1). The classification described by Delbet and popularized by Colonna is widely accepted and used to determine treatment and prognosis (1,3,4,6,8). An intertrochanteric hip fracture in a child is classified as type IV by Delbet-Colonna (8). Six to 15 percent of all hip fractures in children are Delbet type IV (1,3).

Hip fractures in children have a high rate of complications and poor outcomes. Complications include avascular necrosis (AVN) of the femoral head, nonunion, malunion, premature physeal closure, chondrolysis, and infection. The most common and serious complication is AVN (1). It develops due to problems in the vascular support of the proximal femoral epiphysis (2).

Although type IV hip fractures in children are extracapsular and metaphyseal, AVN may occur in up to 14% of these fractures (3). Coxa vara, leg length discrepancy, and nonunion are other significant complications in type-IV hip fractures (2,5). These complications generally occur due to injury of the epiphyseal plate, insufficient reduction or loss of reduction due to unstable fixation (2,5).

There is no consensus on the treatment approach for hip fractures in children (1,2). The degree of initial displacement, the timing of reduction, the quality of reduction, the stability of fixation, decompression of the joint, and weight-bearing can influence the development of complications (1,3). After reduction, stable fixation is crucial (1). Dynamic hip screw and side plate and transpyhseal screw fixation can be chosen in type IV hip fractures in children (2,3).

In this study, we examined the use of adult proximal humeral locking plates for the fixation of pediatric intertrochanteric hip fractures. We hypothesized that fixation of pediatric intertrochanteric hip fractures using adult proximal humeral locking plates would provide more stability and reduce the complication rate. Because; adult proximal humeral locking plates adapt to the proximal femoral anatomy in children. Additionally, the wide proximal end of these plates provided a stronger grip on the proximal femur. Transphyseal fixation is not required for stable fixation in these plates, as it is possible to apply more than one screw, or it is possible to apply screws at an angle of 130 degrees corresponding to the femoral neck-shaft angle. Additionally, these plates can be applied with the minimally invasive plate osteosynthesis technique, thus reducing the risk of complications. We evaluated in the current study the outcomes of using this procedure.

Methods

Study design

This single-center, retrospective study included children who underwent surgery for an intertrochanteric hip fracture using an adult proximal humeral locking plate between January 2012 and January 2019. We used the classification system described by Delbet and popularized by Colonna (8). The inclusion criteria were intertrochanteric hip fractures (Delbet type IV) (Figure 1). Another inclusion criterion was age between 11 and 16 years. The exclusion criteria were nondisplaced fracture, concomitant musculoskeletal and other system injuries, pathological fractures, and a history of previous surgery on the same hip or femur. The University of Health Sciences Türkiye, İstanbul Prof. Dr. Cemil Taşcıoğlu City Hospital Institutional Review Board approved the study protocol (decision number: 395, date: 06.10.2020), and the study was performed under the ethical standards in the Helsinki Declaration. Informed consent was routinely obtained from the parents.

Surgical techniques and postoperative follow-up

In our clinic, fixation of pediatric intertrochanteric fractures with adult humerus proximal plates is performed as described below;

Under general anesthesia, in the lateral decubitus position under fluoroscopy guidance, an incision (approximately 5-7 cm) is performed on the lateral aspect of the thigh, starting from the tip of the trochanter and extending along the long axis of the thigh for the lateral approach of the hip. Evacuation of the intracapsular hematoma is not applied. After a fluoroscopic check of the adequacy of the reduction, the adult proximal humeral locking plate is placed. An unlocking full threaded screw is applied distal to compress the plate to the bone (Figure 2). Then, using the multi-axial screw capability of the plate 4 unlocking and 2 locking screws with a maximum length of 65 mm are applied up to the femoral neck. All proximal screw applications are performed under fluoroscopy control to ensure that no transphyseal fixation occurs. Finally, distal locking screws (at least three) are applied (Figures 3, 4). Anatomical layers are sutured according to the procedure. The hip and quadriceps exercises are started on the third postoperative day. Partial weight-bearing is advised after four weeks, and full weight-bearing is allowed after six weeks.

Radiological outcomes

Sequential anteroposterior and lateral hip radiographs are taken during the follow-up of a patient to evaluate the fracture union time. Bridging of fracture at three cortices, progressive obliteration of the fracture line, and cortical continuity are the criteria used to assess fracture healing. In addition, in the

Figure 1. Radiographic imaging of intertrochanteric fracture of the left femur

Figure 2. Fluoroscopic imaging showing adapting of the plate in the lateral aspect of the femur

Figure 3. Intra-operative picture showing adult proximal humeral plate applied to the proximal femur

currents study, we evaluated complications such as refracture or deformity that may occur due to the removal of the implant by radiographs during follow-up.

Clinical outcomes

We used the Harris hip score (HHS) (9) to assess hip functions. This instrument contains 10 items divided into 3 categories that include pain, function, range of motion (ROM), and deformity. The first component is a patient-oriented questionnaire and comprises the limitations and activities. The second and third portions which comprise leg length and hip ROM (flexion, abduction, external rotation and adduction) are routinely administered by the physician. Each item has its scale, which correlates with the descriptive response alternatives. A higher score indicates good function, whereas a lower score indicates hip dysfunction. Furthermore, we used the Ratliff criteria (10) (based on hip pain, ROM, daily activities, and radiological findings) to evaluate the clinical status during follow-up (Table 1).

Statistical Analysis

We used the Statistical Package for the Social Sciences for Windows version 20.0 software (SPSS Inc. Chicago, Ill. USA) for statistical analyses. Descriptive statistics included mean±standard deviation (SD), median, minimum, maximum, frequency, and ratio values.

Figure 4. Intra-operative final fluoroscopic imaging

Results

Patient demographics and follow-up data

The study included 24 patients (15 male, 9 female) with a mean±SD age of 12.6±1.4 years (range, 11-15 years). The mean±SD surgical procedure time after trauma was 39±14.5 hours (range, 24-72 hours) and the follow-up duration was 34±9.4 months (range, 22-60 months).

Radiological results

The mean±SD duration of fracture union was 12.8±2.2 weeks (range, 10-16 weeks). No residual deformity was observed. The implants were removed after an average of 30±6.5 months (range, 26-48 months). In patients who had implant removal at the time of final follow-up, no complications such as refracture or deformity were observed due to bone weakening in the lateral cortex during the follow-up period.

Clinical results

The mean±SD final HHS was 92±1.9 (range, 89-95). All patients were rated good according to Ratliff criteria.

Complications

There was no AVN, non-union, malunion, limb-length discrepancy, or implant failure at the end of the follow-up period (Figure 5). Seven days after the operation, two patients had a superficial wound infection that healed in less than 10 days. None of the patients needed a second surgical procedure other than implant removal Patients began the rehabilitation program on the third postoperative day and progressive weight-bearing exercises after four weeks (Table 2).

Discussion

Hip fractures in children are rare and account for less than one percent of all fractures in children (1-3). Delbet type IV fractures account for 6 15% of all hip fractures. Because of their low frequency and high rate of complications, no consensus on the treatment protocol for hip fractures in children has been reached (1). Displaced Delbet type IV fractures in children younger than eight years may be treated by closed reduction and an immediate spica casting. Older children with displaced Delbet type IV fractures should be treated with internal fixation. Furthermore, all unstable intertrochanteric hip fractures after reduction, regardless of the child's age, should be treated with internal fixation (3). First, one or two attempts at closed reduction should be made (1,3). Closed reduction should be performed with gentle longitudinal traction because forceful manipulation may compromise the hip vasculature. If the anatomic reduction can not be achieved by closed reduction, open reduction is recommended for displaced fractures. Stable fixation after

Table 1. Ratliff criteria

	Good	Fair	Poor
Pain	None or ignoring	Occasional	Disabling
Movement	Full or terminal restriction	Greater than 50%	Less than 50%
Activity	Normal or patients avoid games	Normal or patients avoid games	Restricted
Radiographs	Normal or some deformity	Severe deformity and avascular necrosis	Severe avascular necrosis, degenerative osteoarthritis, and arthrodesis

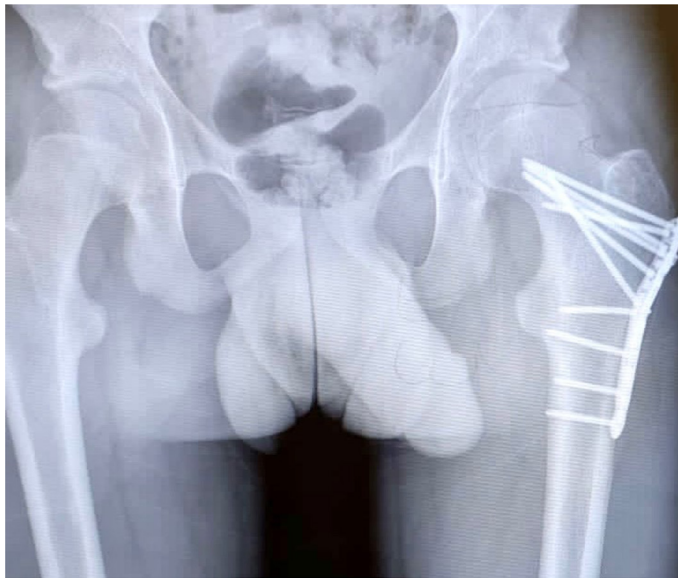

Figure 5. X-ray at fourth-year post-operative showing fracture healing without complications

Table 2. Patient demographics and follow-up		
Age, years, mean±SD		**12.6±1.4**
Sex, n (%)	Male	15 (62.5)
	Female	9 (37.5)
Follow-up, months, mean±SD		34±9.4
Fracture union time, weeks, mean±SD		12.8±2.2
Harris hip score, n, mean±SD		92±1.9
Ratliff criteria, n (%)	Good	24 (100)
	Fair	No
	Poor	No
Complications, n (%)	Superficial wound infection	2 (8)
	Other complications	No

SD: Standard deviation

reduction is essential because it decreases the risk of both malunion and non-union (3). Transphyseal screw fixation is usually recommended despite the risk of damaging the physis. It has been reported that fracture stability is more important than sparing the proximal femoral physis (1,3). It is important to avoid multiple passes of smooth wires or guidewires when stabilizing these fractures (3,11). AVN, malunion, nonunion, premature physeal closure, infection, and chondrolysis are the most commonly reported complications (1-4,6,12). Delbet type IV fractures are generally associated with fewer complications than the other types (4). They have the most favorable prognosis (1).

Hip fractures are associated with higher complication rates and poorer outcomes. The frequency of AVN has been reported between 17% and 47% in hip fractures in children (2,4,13,14). AVN has been reported in Delbet type IV fractures, as many as 14% of cases (3,4,15). Canale and Bourland (6) observed AVN in 1 of 7 patients (14.2%) with type IV fractures. Moon and Mehlman (15) reported AVN in 5% of the cases. The type of fracture, the degree of initial displacement, the age of the patient, and stable internal fixation of the fractures are among the factors associated with AVN (2,14,16-18).

Coxa vara is also a significant complication (1-3). The prevalence of coxa vara has been reported between 20% and 30% (2,14). Canale and Bourland (6) reported coxa vara in 2 of 7 patients (28.5%) with Delbet type IV fractures. Anatomic reduction and stable fixation are the best methods for preventing coxa vara (3,7,15,19).

Non-union has been reported between 2% and 10% of hip fractures in children (3,4,6,9,16). It occurs less frequently when anatomical reduction and stable fixation are applied (2,16,20).

Premature physeal closure has been reported between 5% and 65% of cases (3,6). Premature physeal closure was reported in 28.5% of Delbet type IV hip fractures among children (6). The prevalence of premature physeal closure increases when transphyseal fixation is applied or AVN is present (2,3,6,16). Postoperative infections have been reported in less than 1% of all cases (3).

In this study, we used an adult proximal humeral locking plate to treat 24 children with displaced Delbet-type fractures IV. A pediatric femoral subtrochanteric non-union was treated with an adult proximal humeral locking plate, according to a case study by Cortes et al. (21). In other investigations, the primary treatment for children femoral subtrochanteric fractures were successfully performed using an adult proximal humeral locking device (22-25). However, to the best of our knowledge, no patient has been reported so far in whom an adult proximal humeral locking plate was used to treat a Delbet type IV fracture. We achieved stability and safety fixation with this technique. There was a superficial wound infection in only 1 patient that recovered shortly after antibiotic treatment. We observed no AVN, non-union, coxa vara, premature physeal closure, or chondrolysis. Moreover, none of the patients had poor outcomes. Four weeks after surgery, all patients were allowed to undertake progressive weight-bearing.

Conventional plates are not anatomically pre-formed and must be bent during surgery to accommodate the proximal femoral anatomy. The adult proximal humeral locking plates are pre-contoured to the proximal humerus in adults, and this pre-contoured design adapts to the anatomy of the proximal femur in children. Additionally, the wide proximal end of these plates offers a stronger hold on the proximal femur. The proximal holes of the adult proximal humeral locking plates allow screws to be locked at an angle of 130 degrees, which corresponds to the femoral neck-shaft angle. With this technique, at least 2 rows of long screws towards the femoral neck can be applied, which can provide enough stability that is impossible with conventional methods such as dynamic compression plates, reconstruction plates, or cannulated screw fixation. Because it is possible to apply multiple screws, transphyseal fixation is unnecessary for stable fixation in the adult proximal humerus locking plates. Additionally, a minimally invasive plate osteosynthesis technique

that allows lesser soft tissue dissection and periosteal stripping can be applied using these plates, reducing vascular damage and minor surgical scars. These advantages can decrease the risk of infection, delayed union, and non-union (21-26).

Study Limitations

The difference in our study is that it is the first publication in the literature with excellent results using these plates in pediatric Delbet type IV hip fractures. The limitations of this study are the small number of patients, the short follow-up period, and lacking comparisons with other techniques. The main strength is its single-center design to display the results of procedures applied by the same surgeon team.

Conclusion

In conclusion, there has been no consensus on the treatment of hip fractures in children, which challenges orthopedic surgeons. We concluded that gentle anatomic reduction and stable fixation without crossing the physis can decrease the risk of complications for treating Delbet type IV hip fractures in children. The findings of this study suggest that the fixation of Delbet type IV hip fractures in children using an adult proximal humeral locking plate may be an acceptable treatment option.

Ethics

Ethics Committee Approval: The University of Health Sciences Türkiye, İstanbul Prof. Dr. Cemil Taşcıoğlu City Hospital Institutional Review Board approved the study protocol (decision number: 395, date: 06.10.2020).

Informed Consent: Informed consent was obtained from the parents.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices - Concept - Design - Data Collection or Processing - Analysis or Interpretation - Literature Search - Writing: E.T., E.A.T.

Conflict of Interest: No conflict of interest was declared by the authors.

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