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Pathological Fractures of the Proximal Femur in Children and Adolescents Treated with LCP Paediatric Hip Plate

Patologické zlomeniny proximálního femuru u dětí a dospívajících léčené LCP dětskou kyčelní dlahou

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ABSTRACT

PURPOSE OF THE STUDY

Exploring the therapeutic potential of pathological fractures treatment of the proximal femur in childhood with LCP paediatric hip plate system according to the principles of AO.

MATERIAL AND METHODS

Six children with pathological fractures of the proximal femur and with an unicameral bone cyst have undergone surgery in our institution, in the period between June 2018 up until December 2020. All patients were young boys with a mean age of 11.83 ± 3.43 years. According to the classification of Delbet-Colonna, three of the fractures were Type IV – intertrochanteric fractures and three were Type III – basocervical fractures. ccording to the AO Trauma classification, one of the fractures was complete transtrochanteric multifragmentary (31–M/3.2.III), two were complete transtrochanteric simple (31-M/3.1.III), one was Complete basocervical multifragmentary (31-M/3.2.II) and two were complete basicervical simple (31-M/3.1.II). All patients have undergone open reposition and osteosynthesis with a 130° LCP pediatric hip plate system (DePuy Synthes Pediatric LCP Plate System). In four of the patients, one or two of the proximal locking screws pass through the growth plate, to ensure more stability. The anatomical correction of the proximal femur has been measured through the cervico-diaphyseal angle, consolidation of the fracture, the spontaneous reparation of the cyst according to the Capanna classification and cystic index, presence of avascular necrosis of the epiphysis, shortening of the extremity, and functional grading by the Musculoskeletal Tumor Society (MSTS) staging system. The Mann-Whitney (Wilcoxon W) test was used for data processing.

RESULTS

The mean timing of the follow-up after the surgery was 22 months (range 6–32). A radiographically supported consolidation of the fracture has occurred at an average timing of 4.8 months (range 3–6) in all patients. There is no clinical or radiological evidence of postoperative avascular necrosis in any of the patients. According to the classification of Capanna, in five of the six patients a spontaneous reparation of the cyst has occurred. In one of the cases, the reparation is classified as grade II with a pathological cystic index of 2.27. A postoperative correction of the varus fracture deformity of the proximal femur has been achieved in all children. The cervical-diaphysary angle of 112.50° preoperatively has been corrected to 137.17° (p=0.002). The achieved correction is lasting and the average value of the CDS at the final follow-up is 138.17° (p=0.794). Intraoperative correction, statistically equal to the CDA of the healthy side (p=0.942) is achieved with this operative technique. Data from the MSTS show functional correction on the third postoperative month with 38.33% of the norm (p=0.002) and 85% on the final follow-up (p=0.002). A contralateral distal femoral surgical epiphysiodesis by the method of Métaizeau has been used for the correction of the difference in the length of the extremities (with an average of 2.9 cm).

CONCLUSIONS

Osteosynthesis with an LCP paediatric hip plate system gives the opportunity for anatomical correction of the proximal femur with a low risk of avascular necrosis and achieving optimal functional results in pathological basocervical and intertrochanteric fractures in childhood. The use of 5mm plates and penetration of the proximal screw through the growth plate holds an increased risk of growth disruption.

Key words: LCP paediatric hip plate system, pathological fracture, unicameral bone cysts, proximal femur.

INTRODUCTION

Unicameral bone cysts (UBC) or simple/solitary bone cysts are the most common etiology of pathological fractures in children (21). The second most common localisation of this type of fractures is the proximal femur, with the first being the proximal humerus (1). In 80% of patients the first symptom of the presence of a bone lesion is a fracture (19). Depending on the age of the child, the therapy consists of skeletal or skin traction, primary cast immobilisation, operative with external fixators, or open or closed reposition with titanium elastic intramedullary nailing (TEN), screws or plates (3, 8, 11, 16, 26). **The aim** of the research is a retrospective analysis of osteosynthesis with an Locking Compression Paediatric Hip Plate system (DePuy Synthes Pediatric LCP Plate System) (14) in children up to 18 years of age with pathological basocervical and intertrochanteric fractures.

MATERIAL AND METHODS

Six children with pathological fractures of the proximal femur and with an UBC (unicameral bone cyst) have undergone surgery in our institution, in the period between June 2018 until December 2020. The diagnosis was obtained by radiological examination in two projections, as well as computer tomographical scanning. At the time of surgery, biopsies of the cystic lesions were obtained, hence confirming the initial diagnosis. All patients are young boys with a mean age of 11.83 ± 3.43 years. According to the classification of Delbet-Colonna, three of the fractures were Type IV – intertrochanteric fractures and three were Type III – basocervical fractures. According to the AO Trauma classification, one of the fractures was complete transtrochanteric multifragmentary (31-M/3.2.III), two were Complete transtrochanteric simple (31-M/3.1.III), one was complete basocervical multifragmentary (31-M/3.2.II) and two were complete basicervical simple (31-M/3.1.II). Table 1 shows the detailed patient characteristics at the time of presentation. In five of the six children, the operative management has been carried out between 48 and 72 hours from the time of the event of the fracture, whilst in one of the children surgery was performed after a 15-day direct supracondylar extension, due to a simultaneously persisting SARS-CoV-19 infection.

Surgical technique

The patient is placed in a lateral position and securely held with adjacent props on the lumbar spine and the anterior superior iliac spine. X-ray images are taken in the horizontal plane. The operative technique includes a lateral and anterolateral approach of the intertrochanteric region. Additionally, a Z-capsulotomy by the method of Ganz has been performed in three of the cases (6). The walls of the pathological cyst are scraped with the help of a curette and the material is sent for histological verification. The operative wound is cleansed with isotonic solution, to remove all free micro fragments. In multi-fragmented fractures, the attached to the periosteum particles are not removed. Reduction is achieved by gentle traction, leg positioning and direct reduction through traction with a hook in line with the femoral neck. Temporary K-wire stabilisation with two or three divergent wires is performed. Fixation with a 130° LCP pediatric hip plate is carried out, strictly following the step-by-step instructions given as a recommendation by the producer and AO Surgery Reference manuals. Four 5.0-mm plates and two 3.5-mm plates, which correspond to the body mass index of the child, have been used. Compression screws have not been used for the third entrance of the proximal part of the plate. Instead, a locking screw has been inserted in the given area. In five of the six patients, one or two of the proximal screws pass through the growth plate for additional fixation. Additional fixation with one cortical screw has been applied in the patients with multi-fragmented fractures. Routine closure is performed for the surgical wound. Definitive radiological images are taken at the end of the surgical intervention.

Postoperative management

External immobilization has not been applied in the management of the six patients. Range-of-motion exercises were started in the immediate postoperative period to prevent stiffness. On the second postoperative day, passive flexion with the help of a motor operated passive motion device has been applied. In the course of five days, an augmentation of the range of motion from 30 degrees to 45 degrees was carried out. Throughout the postoperative period, the patient can be mobilised and apply partial weight bearing with the aid of crutches. The standard weight bearing adjustment would be partial at 6 weeks and full at 12 weeks postoperatively.

Clinical and radiographic controls were performed at 6, 12 and 24 weeks and further controls at 6–12 months postoperatively. Full leg bearing without walking aid is allowed after radiographic evidence of consolidation. Swimming and non-contact sports are recommended one year postoperatively. In two cases, the implants were

Table 1. Data on 6 pediatric patients with pathologic basicervical and interthrochanteric fractures

Case №	Age (years)	Delbet-Colonna class.	AO Trauma classification	130° LCP ped. hip (mm)	Follow-up (months)	Cystic index		AVN	Capanna class.	Time of consolidation (months)	Shortening (mm)
						Intra-op	Final follow-up				
1	7	IV	31-M/3.1.III	3.5	30	1.44	2.27	No	gr II	6m	≤ 5
2	9	III	31-M/3.2.II	5.0	19	2.03	not reported	No	gr I	4 m	30
3	14	IV	31-M/3.1.III	3.5	22	1.11	not reported	No	gr I	3 m	≤ 5
4	11	IV	31-M/3.2.III	5.0	24	0.75	not reported	No	gr I	6 m	≤ 5
5	16	III	31-M/3.1.II	5.0	32	1.98	not reported	No	gr I	6 m	≤ 5
6	14	III	31-M/3.1.II	5.0	6	0.97	not reported	No	gr I	4 m	28

Fig. 1. Case № 4. a,b,c – diagnostic and intraoperative X-rays, d,e,f – X-ray on the 3th, 6th (bone healing) and 18th month after the operation, g,h – final follow-up X-ray.

removed after evidence of complete consolidation and reparation of the bone lesion up to grade I according to the Capanna classification.

A follow-up of the anatomical recovery of the proximal femur has been carried out by the measurement of the cervical-diaphysary angle (CDA) and observation of the consolidation of the fractures. Spontaneous reparation of the cyst by the classification of Capanna (2) and the cystic index (12), the presence of avascular necrosis of the epiphysis, shortening of the extremity. and a functional grading by the Musculoskeletal Tumor Society (MSTS) system (5) have also been used. The cystic index is determined via AP radiography, performed immediately after the surgical intervention. Prior to surgery, all parents provided a signed, informed consent for their children to undergo the procedures and participate in the study.

Statistical methods

The sample size is very small, and Student t-test is unapplicable. A non-parametric approach is considered to be more adequate. Different samples may be considered as independent. So, Mann-Whitney (Wilcoxon W) test may be used as a non-parametric analogue to t-test. Exact significance (p-value) is calculated for decision making. The probability for type I error (significance level) for two-sided alternative was fixed at 5%. All calculations and hypothesis testing are performed with IBM® SPSS® Statistics, ver. 26.

RESULTS

The mean follow-up after the surgery was 22 months (range 6–32). A radiographically supported consolidation of the fracture has occurred at 4.8 months (range 3–6) in all patients. There has not been any incident, involving loosening or breakage of the plate, nor any disengagement of the screws. There is no clinical or radiological evidence of postoperative avascular necrosis (AVN) in any of the patients.

According to the classification of Capanna, in five of the six patients a spontaneous reparation of the cyst has occurred. In the final control follow-up, the reparations have been classified as grade I. One lesion has been classified as grade II, meaning that residual radiolucency was observed radiographically in the final follow-up (Fig. 2). In this particular patient, a pathological cystic index of 2.27 has still been estimated at the 30th postoperative month. Due to the present reparation in all other patients, such an index could not have been determined.

A postoperative correction in the varus fracture deformity has been achieved in all children (Table 2). Cervical- diaphysary angle of 112.50° preoperatively is corrected to 137.17° (p=0.002). The achieved correction is lasting and the mean value of the final control follow-up of the CDA is 138.17°, whilst a statistically significant difference compared to the intraoperative one (p=0.794) is missing. With the operative technique, an intraoperative correction of the CDA statistically equal to the CDA of the healthy side (p=0.942) is achieved. One patient (case № 4) (Fig. 1) with a 31–M/3.2.III fracture developed a mild coxa valga deformity mainly due to slight over-angulation of the plate, but the difference did not merit any further treatment as it did not exceed 10 degrees. Furthermore, a slight coxa valga deformity in the hip joint considered healthy in the given patient has been observed.

Growth of the operated bone was found to be normal in four patients. Postoperatively, a clinically significant difference in the length of the extremities has been determined in two of the children. A 5.0-mm 130° LCP hip plate has been utilized in both children. In one of the cases, the shortening has been observed on the sixth postoperative month. The present difference has been observed to increase with time. A potential growth plate injury is considered to be the causative factor.

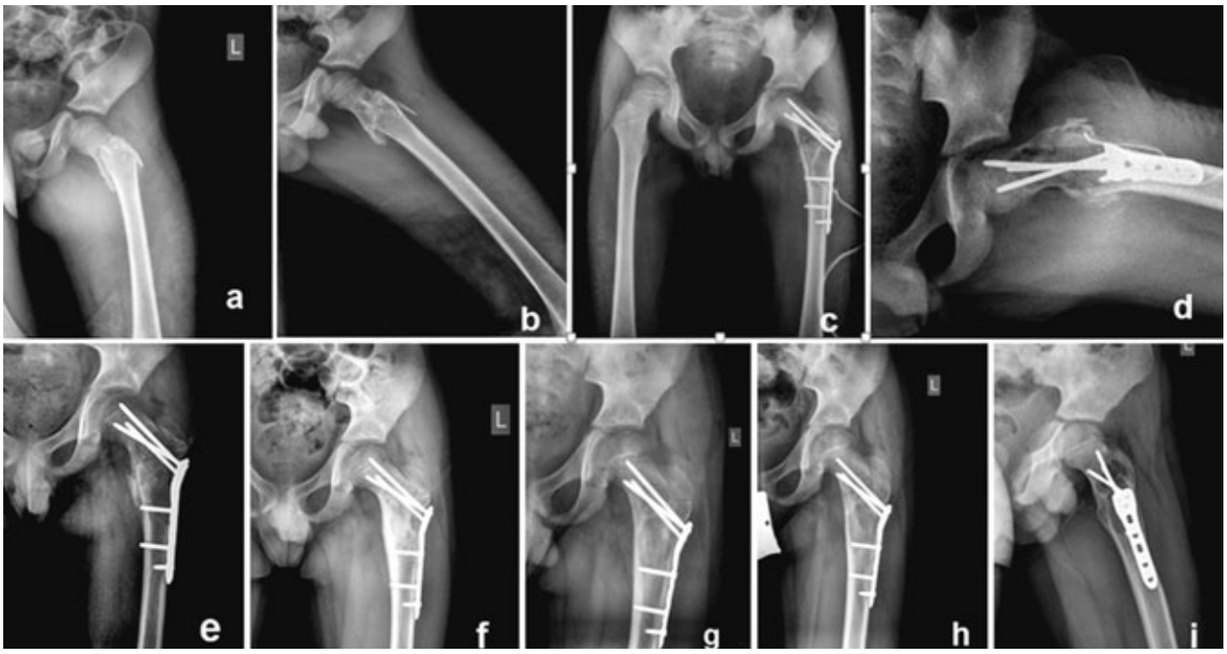

Fig. 2. Case № 1. a,b,c,d – diagnostic and intraoperative X-rays, e,f,g – X-ray on the 3th, 6th (bone healing) and 18th month after the operation, h,i – final follow-up X-ray, Capanna grade II.

In the second case (Fig. 3) the shortening has most probably begun before the fracture itself. This has been considered plausible due to the 28-mm difference, which has been observed on the third postoperative month in the equal CDA of the two extremities. Another reason is the possible intraoperative overcompression between the fragments. This probable technical error cannot be related to osteosynthesis. A contralateral distal femoral surgical epiphysiodesis by the method of Métaizeau has been used for the correction of the difference in the length of the extremities (15). In all cases with plates of 3.5 mm and in two of the them with a 5-mm plate, the lower extremities are equal in length, as the proximal screws migrate distally from the growth plate in time (Figs. 1 and 2).

Data from the MSTS show functional recovery on the third postoperative month with an average of 38.33% from the norm (p=0.002) and with an average of 85% on the final control follow-up (p=0.002) (Table 3). The range of motion in the hip joint that has undergone surgery is normal, with an exception of a slight decrease in internal rotation. It differs from the hip joint considered healthy by 10 to 15°.

DISCUSSION

Pathological fractures proximal femur are characterised by insufficient bone substrate, requiring stable osteosynthesis, unlike other traumatic fractures of the proximal femur. Because the results of various management methods are heterogeneous, no single method has emerged as the standard of care. Basocervial and intertrochanteric localisation of the fracture creates a difficult environment for the use of elastic intramedullary nails. This technique has proven to have therapeutic potential in cases with subtrochanteric and diaphyseal trau-

Table 2. Changes in CDA in degrees – preoperatively, postoperatively, and final follow-up of both the fractured side and healthy side

Case №	CDA (°) pre-op	CDA (°) intra-op	CDA (°) healthy side	CDA (°) at final follow-up
1	100	130	135	137
2	113	138	140	140
3	111	125	132	126
4	118	158	148	158
5	120	135	134	136
6	113	137	135	132
Mean	112.50	137.17	137.33	138.17

Fig. 3. Case № 6. a,b – diagnostic X-rays and CT, c,d – X-ray on the 4th month after the operation (bone healing), e –X-ray on the 6th month after the operation, on the opposite side – percutaneous epiphysiodesis with transphyseal screws (PETS) for limb-length discrepancies of 2.8 mm.

matic and pathological fractures (7, 23, 30). Short proximal fracture fragment TEN osteosynthesis, however, is with a higher complication rate and carries risk of unplanned revision surgery (18, 20, 27).

There are few case reports in current literature of other osteosynthesis therapy in pediatric pathological proximal femur fractures. Havránek reports two children treated with a proximal femoral AO-ASIF angled-plate, which recovered well without sequelae (8). Miu A. reports a series of 27 patients with the same pathology (16). Intramedullary nailing with two TEN and filling with substitute materials has been applied in two of the patients. PFNA and filling with Arex Bone was been used in one of the patients and eight patients have undergone minimally invasive resection-biopsy and filling with replacement material. One particular case relapsed and needed osteosynthesis with the help of an external fixator. Dormans and Pill classified pathological fractures of the proximal femur with UBC into six types based on the location and size of the cyst and the presence or absence of the lateral buttress (4). They recommended, in addition to curettage and grafting, the use of a pediatric hip screw and side plate in cases where the lateral buttress is compromised for skeletally immature hips in addition to selective postop spica application. Jamshidi has used a proximal locking plate and a fibular strut al-

Table 3. Changes in MSTS in points and percentage – preoperatively, on the third postoperative day, and final follow-up

Case №	MSTS pre-op (points)	MSTS at 3months (points)	MSTS at 3 months (%)	MSTS at final follow-up (points)	MSTS at final follow-up (%)
1	1	7	23.33	26	86.67
2	2	15	50.00	23	76.67
3	0	14	46.67	27	90.00
4	1	11	36.67	29	96.67
5	2	12	40.00	27	90.00
6	0	10	33.33	21	70.00
Mean	1	11.5	38.33	25.5	85.00
	Improvement % = 30 *100%				

lograft in six fractures from a series of 14 children with UBC (9). Complete healing (Capanna's class I) was seen in ten cysts. Mean healing period was 14.1 ± 5.1 (9–24 months). One patient presented with superficial infection, one with heterotopic ossification, one with mild coxa vara, and the mean MSTS score was 99.5%.

The choice to perform osteosynthesis with an LCP pediatric hip plate in the given fractures is based on our 15 years of experience in the application of this type of synthesis in more than 400 proximal femoral osteotomies and data from the medical literature for their application in osteoporotic and insufficient bone (10, 13, 24, 25, 28). Our results show that the 130° LCP paediatric hip plate system gives the opportunity for intraoperative long-lasting anatomical correction. Data from the follow-up of the CDA during the final follow-up supports the correction preservation. We recommend early surgical treatment, which gives the chance for the symptoms of pain to be reduced, whilst at the same time the ability to obtain a biopsy for histological examination, as well as early mobilization. The proposed osteosynthesis can be performed at a later stage, as in one of our cases described above, in which the surgery was postponed due to a persistent SARS-CoV-2 infection.

The technique used is non-traumatic and does not disturb the epiphyseal growth (16, 17). None of the patients from the series have developed avascular necrosis. This could be due to the relatively little possibility for its development in basocervical and intertrochanteric fractures. Sparing of the *a. circumflexa femoris medialis* throughout the surgery and the application of frontal Z-capsulotomy is another potential factor for the successful prevention of avascular necrosis.

Healing of the fractures went uneventfully. All cases showed early callus formation at 6 weeks postoperatively, as well as complete bony consolidation at 24 weeks postoperatively. This correlated to the older age of the patients, in addition to the rigidity of fixation and the angular stability of the plate-screw system provided by the LCP paediatric hip plate system. At the final follow-up, complete consolidation was achieved without any case of non-union.

Spontaneous reparation of the cyst, which has occurred in our patients, cannot be related to the used synthesis. Drainage of the cyst at the fracture and the performed intraoperative curettage are both causative factors (11), as well as the additional decompression during capsulotomy.

There is no disruption of the growth plate development with the use of 3.5 mm in diameter material, which is supported by the migration of the proximal screws distally. It could be accepted, that the use of a 5.0 mm implant and in the passing of more than one screw through the physis, there is a potential growth arrest of the femur. We agree with other authors when it comes to the observation of early closure of the epiphysis in pathological fractures (22, 29). Hence, we recommend radiographic control of the lower extremities in AP projections every six months up until completion of growth.

Intraoperative measuring of the length of the femur is an important condition for prevention of overcompression between the fragments. The stability of the osteosynthesis allows for early verticalization and partial weight bearing. This ameliorates the functional and emotional state of the children and the fast return to a normal social life. Our patients with a follow-up of over two years show an MSTS score similar to the normal range.

Shortcomings of our study are the smaller patient number and the lack of a control group treated with another technique.

CONCLUSIONS

We believe that with strict indications for surgery, an exact operative and an experienced team of surgeons, an open reposition and metal osteosynthesis with a 130° LCP paediatric hip plate system of pathological basocervical and intertrochanteric fractures in children and adolescents gives a good possibility for anatomical recovery and consolidation of the fractures. The stable synthesis allows for early mobilization and a minimal risk of avascular necrosis.

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