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TECHNICAL NOTE • HIP - PAEDIATRICS

Unilateral uniplanar modular external fixator for percutaneous proximal femoral osteotomy in children: surgical technique

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Abstract
Varus derotation femoral osteotomy (VDFO) is a commonly used surgical procedure in association with pelvic osteotomy for dislocated hip in developmental hip dysplasia. Several types of internal fixation devices were described in the literature, but none of them showed a superiority or a lower rate of complication over the others. Different types of external fixator were also described for proximal osteotomy fixation with good results. We describe the surgical technique of the VDFO using a modular external fixator with an illustrative case.

Keywords Congenital hip dysplasia · Developmental hip dislocation · External fixator · External fixation device · Femoral osteotomy

Introduction

The physiological development of hip joint requires an anatomical and a stable placement of the femoral head inside the acetabulum. Otherwise, the hip joint will not mature correctly heading to a condition known as developmental dysplasia of the hip (DDH) [1]. In such condition, the aim of the treatment is to obtain a stable and concentric reduction avoiding avascular necrosis (AVN) and the need of revision procedures [2].

Late presentations of DDH with or without dislocated hip joint may still occur, despite the clinical and ultrasonography screening program, mainly because of late presentation, relapse or recurrence of instability due to an incorrect early treatment [3, 4]. Dislocated hip joint represents the most severe stage of DDH and, in children older than 2 years, usually requires an aggressive approach based on bone reconstructive procedure [2, 3]. In particular, older children with dislocated hip usually required an open reduction to restore normal joint relationships [3]. Furthermore, patients with residual acetabular dysplasia usually required pelvic osteotomy (PO) [2, 5]. The POs are commonly subdivided into [2] redirectional orientation osteotomies (such as [6]), volume reducing osteotomies (e.g., [7, 8]) and salvage osteotomies.

Varus derotation femoral osteotomy (VDFO) was described to correct valgus and antiversion deformity of the proximal femur, also known as coxa valga-antiversa, which may be present in DDH, and is usually associated with PO [9–11]. The aim of the VDFO is to obtain a concentric reduction of the femoral head inside the acetabulum [12].

For this technique, several implants have been proposed for femoral osteotomy fixation, but no one showed superiority or a lower rate of complication over the others [13, 14]. Several types of external fixators (EF) as well were associated with good results and low complications rate [15–17].

The advantages of using EF instead of implantable devices are the minimal surgical exposure and no need for surgery for removal, and it allows an intra-operative gradual adjustability of the malformation correction.

The unilateral uniplanar modular EF is a commonly used device for acute care of trauma, and its application is familiar for most of the orthopedic surgeons. These points, together with the simplicity of the assembly of the frame, make it an interesting osteosynthesis device for VDFO.

The aim of this study was to describe a surgical technique for VDFO in the treatment of coxa vara associated with DDH using a modular EF and reporting one illustrative case.

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Indications

Proposed indications for VDFO using modular EF are: subluxated or dislocated hip (Tönnis 2–4 [18]); association of coxa valga-antiversa; and patients aged between 2 and 5 years (Table 1) [2, 3]. Neurological disease or syndromes should be considered contraindications for using this technique since the osteoporosis is commonly associated with this pathology and the angular stable locking plates are preferable [19].

Surgical technique

Preoperative planning

Preoperative assessment comprehended a standard orthopedic clinical examination, pelvis X-rays (antero-posterior and frog-leg view projections) and MRI [11, 20–22]. The frontal and sagittal plane deformities of the proximal femur are carefully evaluated in this phase. The valgus deformity is evaluated by measuring the femoral neck-shaft angle (NSA) in the antero-posterior X-ray of the pelvis. The desired position of the femoral head after surgery is in the center of the acetabulum. The correction angle is calculated by subtraction from the native NSA the estimated postoperative NSA (Fig. 1). The AP X-rays of the pelvis are also fundamental to evaluate the acetabular index. The femoral antiversion could be evaluated clinically with the method described by Ruwe et al. [23] or with the MRI by calculating the angle between the femoral axis and the posterior condylar axis [11].

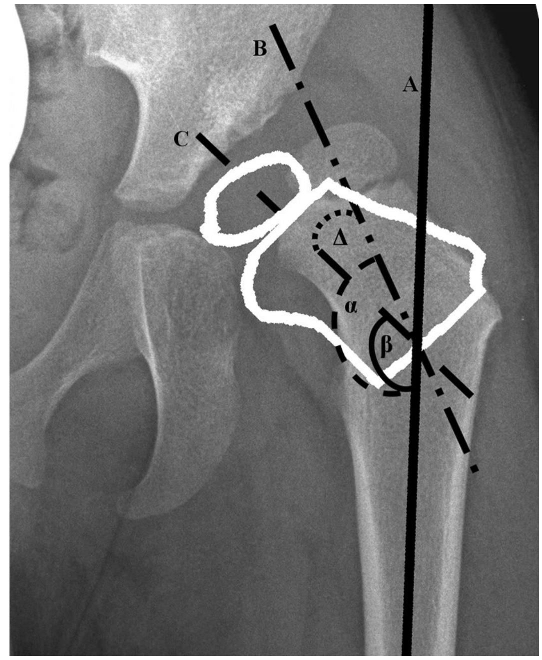

Fig. 1 Preoperative planning for proximal femur valgus deformity correction. The white shape represents the postoperative position of the femoral head which should be placed in the center of the acetabulum. The continue straight line (A) represents the diaphyseal axis, the dotted and dashed straight line (B) represents the preoperative neck axis, and the dashed straight lined (C) represents the postoperative, desired neck axis. The α (dashed curved line) is the preoperative neck-shaft angle (NSA), the β angle (continue curved line) presents the postoperative NSA, and the Δ angle (dotted curved line) is the estimated correction angle

Surgical technique

Step 1: Patient positioning and surgical field. The patient is placed supine on a radiolucent table. A sterile field is set starting from the inferior part of the ipsilateral belly (including the iliac wing) down to the foot with the limb draped free.

Step 2: *Arthrogram and open reduction.* An arthrogram is performed first followed by an open reduction obtained through the most comfortable surgical approach for the surgeon.

Step 3: Pelvic Osteotomy. The choice of the type of the PO mainly depends on the surgeon's preference [3]. The most commonly used PO is the Salter innominate osteotomy, the Zanoli-Pemberton pericapsular acetabuloplasty ore the Dega osteotomy. The authors prefer to perform the PO before the VDFO. This allows to direct the femoral head in the center of the new shape of the acetabulum during the step 8.

Step 4: Proximal half-pins placement. The VDFO starts at this time. This step may be facilitated by internal rotation of the limb and by placing a 1.5 mm as femoral intercondylar axis reference. Four or five millimeters half-pins should be used. A 1.5-mm reference K-wire is placed in the center of the femoral neck, representing the valgus and antiversion deformity. The first screw of the EF is placed in the medial third of the femoral neck parallel to the reference K-wire using the EF clamp as guide. The second screw is placed parallel and lateral to the first one (Fig. 2a, b).

Attention is required to avoid passing through the femoral head and the great trochanter growth plates;

Step 5: Distal half-pins placement. The first distal screw, of the same size of the proximal ones, is placed perpendicular to the femoral diaphysis, 4–5 cm distal to the osteotomy level at a sufficient distance to avoid the contact with the proximal half-pins. The offset relative to the proximal screw (corresponding to the femoral neck version correction) is calculated by a sterile goniometer using a preoperative planned correction value as reference (Fig. 2c).

The second pin is placed parallel to the first at the farthest point allowed by the EF clamp;

Step 6: Intra-operative measurements. The knowledge of the starting angles between the proximal and distal screws on the frontal and the sagittal planes is critical to check the exact amount of the correction after the osteotomy in the step 8. Using a sterile goniometer, the frontal plane and the sagittal plane angles of the proximal screw in relation to the plane of the distal screws are annotated (Fig. 2c, d).

Step 7: *Femoral Osteotomy*. The aim is to perform the osteotomy in the intertrochanteric area. The level of the osteotomy is found using fluoroscopy with a C-arm. Through a small (1–2 cm) direct lateral approach to the femur, the intertrochanteric osteotomy is made by performing multi-holes with a 1.5-mm K-wire and completed with an osteotome (Fig. 2d).

Step 8: Femoral deformity correction. The proximal and distal femoral segments are now detached, and they may move freely. Each segment is integral with its own pair which may be used to move the relative bone segment. Starting from the initial position of the screws, which represents the initial position of the femoral segments, the proximal screws are moved in the frontal and in the sagittal planes of the degrees calculated in the preoperative planning in order to correct the valgus and the antiversion deformity. When the planned correction is reached, the external clamps are connected using 2 radiolucent bars and tightened. At the end of the correction, the four pins

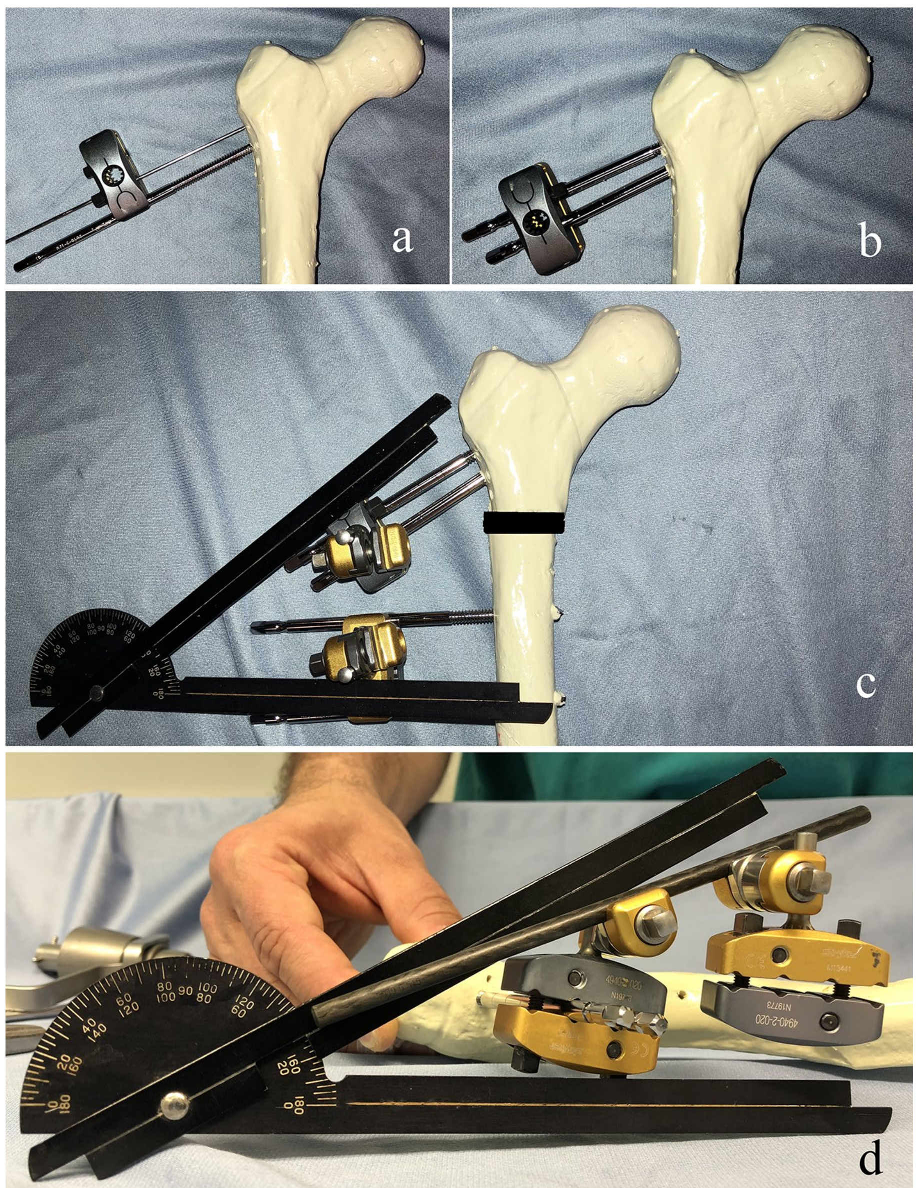

Fig. 2 **a** 1.5-mm K-wire is placed in the center of the femoral neck and is passed through the superior hole of the EF clamp; the inferior hole of the EF clamp is used as a guide for first half-pin insertion, **b** the guide K-wire is removed, and the second proximal half-pin is inserted through the superior hole of the EF clamp; **c** after the placement of the distal screws, the AP starting angle between proximal and distal half-pins is annotated. The intertrochanteric osteotomy level is showed (black line); **d** the starting amount of antiversion is calculated by a sterile goniometer. The knowledge of the exact initial angles on the two planes is critical to check the exact amount of the correction after the osteotomy

should be aligned in the sagittal plane (Fig. 3). A biplanar fluoroscopy check is now performed.

At this point, an intra-operative test of stability of the hip joint is performed [24]. If the femoral head is stable inside the acetabulum in neutral position, no further correction is required; if it is not, more correction or femoral shortening could be added [2, 3].

Step 9: *Hip casting*. A standard hip spica cast, with malleolar inclusion, is applied with particular care to keep clean the pin tracts. A wide cut of the cast is performed around the EF, and the pin tracts to allow their periodic medications. A pelvic X-ray is performed at the end of the surgical procedure (Fig. 4).

Postoperative care

The hip spica cast is renewed after the first postoperative month for a total of 2 months of immobilization (for PO protection). After the removal of the casts, the patient is allowed to start mobilization of the hip and weight bearing, avoiding traumatic activities. The EF is removed under sedation when the osteotomy shows a complete healing at X-ray. This is defined as the appearance of at least 3 of the 4 femoral corticals evaluated in the AP and lateral X-rays views [25]. A pelvic X-ray for hip evaluation is required at 1, 2, 3, 6 and 12 months after surgery. The indications, surgical steps, and the postoperative care are resumed in Table 1.

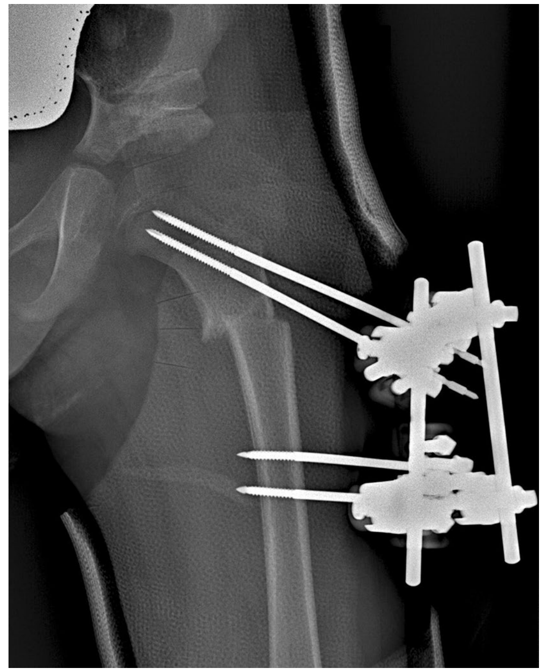

Fig. 4 Postoperative X-rays

Illustrative case

A 3-year girl with DDH and dislocated left hip presented to authors attention. The girl showed a limping gait on the left side. At the clinical examination, a limited ROM was noted with a 2-cm limb length discrepancy. The Harris Hip Score [26] was 61.3, and the application of modified McKay criteria [2] resulted in a grade III.

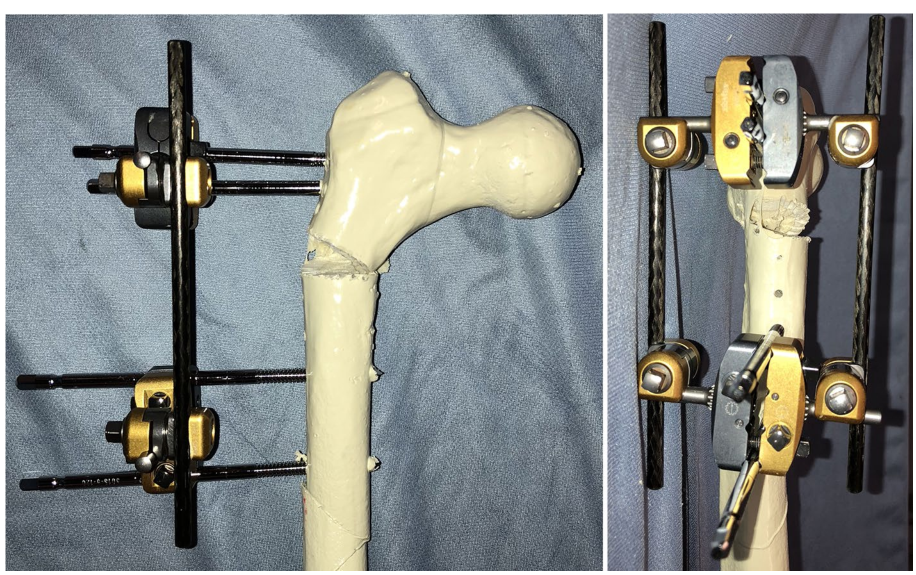

Fig. 3 Securing of the EF frame with 2 radiolucent bars; final result obtained after osteotomy and angular correction

Table 1 Summary

Decision making	
Indications	*Contraindications*
Tönnis Grade 2 or worse	Neurological disease
Proximal femur valgus and antiversion deformity	Syndromic patients
Age between 2 and 5	Lack of EF compliance
Surgical steps	
Step 1: Patient positioning and surgical field	*Step 6:* Intra-operative measurements
Step 2: Arthrogram and open reduction	*Step 7*: Femoral osteotomy
Step 3: Pelvic osteotomy	*Step 8:* Femoral deformity correction
Step 4: Proximal half-pins placement	Step 9: Hip casting
Step 5: Distal half-pins placement	
Postoperative care	
6–8-week hip spica cast, no weight bearing	
EF removal after the healing of the osteotomy	
Pelvic X-ray at 1, 2, 3, 6, 12 months after surgery	

X-rays showed a dislocated hip (Tonnis grade 3) [18], acetabular dysplasia and proximal femur valgus deformity (NSA: 153°, Fig. 5a), and the MRI showed a femoral antiversion of 47°. The preoperative planning showed that the femoral head became centered inside the acetabulum at about 135° of NSA (Fig. 1).

A Zanoli-Pemberton PO [2] was performed associated with varus and derotation femoral osteotomy (VDFO) with modular EF.

The hip spica cast was maintained for 61 days, and EF time was 76 days. Operative removing time of the EF was 15 min (including sedation and wound dressing). No complications were detected.

At 1-year follow-up, the patient showed a Harris Hip Score of 89 points and a good (grade II) result according to the modified McKay score. X-rays showed a neck-shaft angle normalization (132° at 1-year follow-up, Fig. 5b) without significant differences among NSA values evaluated postoperatively, at EF removal time and last follow-up. The center angle of Wiberg passed from 0° to 33°.

Discussion

Treatment of subluxated or dislocated DDH in older children is a tricky condition. There are concordant opinions about the need for an open reduction and PO [2], but there is not the same agreement about the utility of the VDFO. Some authors reported inefficacy or a possible negative effect of VDFO on the hip biomechanics [27]. On the other hand, other studies showed how an altered anatomy of the proximal femur could lead to instability and worst outcomes, requiring its correction [12, 15–17, 28, 29]. Karadimas et al. [9] showed that best outcomes were correlated with no more than 100°–110° of the NSA after the osteotomy. In particular, they reported that the groups of patients with postoperative NSA between 100° and 110° and > 110°

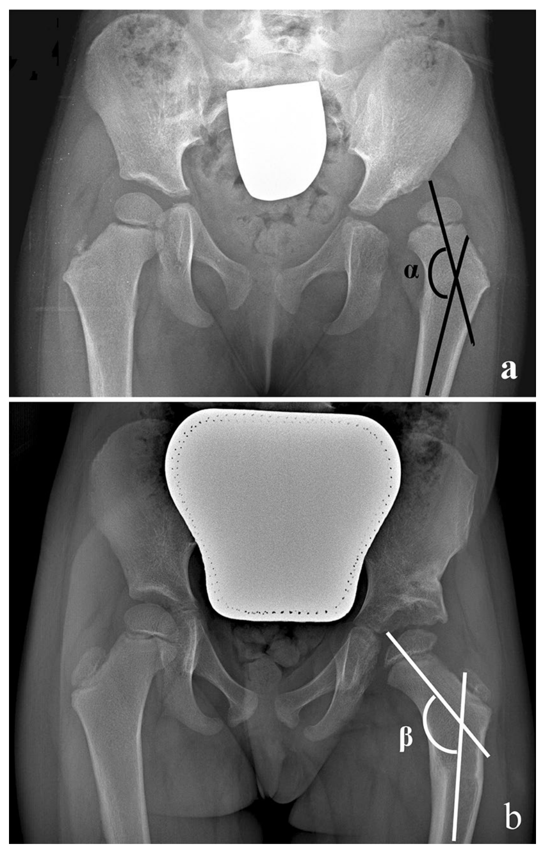

Fig. 5 **a** Preoperative and **b** and 1-year follow-up X-ray of the illustrative case. Patient was a 3-year-old female with DDH, dislocated left hip, acetabular dysplasia and coxa valga-antiversa with a NSA of 153° (the α angle in the picture). After 1-year from left hip surgery, X-rays showed a reduced hip, normalized acetabular index and NSA of 132° (the β angle in the picture)

showed values of NSA and center-edge angle of Wiberg similar to the contralateral, normal side after long-term follow-up. Other authors suggested to avoid a postoperative NSA of less than 115°–120° and to exceed 20° of correction in order to avoid the weakening of the hip abductors which may be result in Trendelenburg gait [30].

The authors calculate the total amount of correction and the postoperative NSA during the preoperative planning. This is represented by the NSA angle in which the femoral head is centralized into the acetabulum (Fig. 1). A test of stability [24] is performed intraoperatively to check the joint relationships. The authors, furthermore, prefer to avoid correction greater than 20°–25° or a postoperative NSA which falls outside the range of normal values (124°–136° [31]). About antiversion, the intention is to return it to a physiological value [13].

Furthermore, association with PO and VDFO showed a good result in long-term follow-up study [32].

Several methods and fixation techniques for proximal femoral osteotomy in DDH were described with a lack of evidence of superiority of one of them; in particular, no one of the described fixation device showed a lower rate of complication [14].

Beauchesne et al. [33] reported 5 fractures out of 137 cases treated with blade plate. Webb et al. [13] reported 1 device failure out of 81 osteotomies performed and 3 wound complications. Hau et al. [14] showed a complication rate of 9% requiring revision surgery in 3%. The internal fixation devices require a second surgery for their removal which could be correlated with complications. The EF, on the other hand, may be removed under conscious sedation without the need of operative room taking only few minutes.

About hip spica cast, there is no difference between internal devices and EF. In the majority of cases, in fact, the femoral osteotomy is associated with PO which required a cast protection in the postoperative care. Other studies reported successful use of the EF in proximal femoral osteotomy for DDH [12, 15] or other pathologies [34, 35]. At the best of our knowledge, this is the first study which reported the use of a unilateral uniplanar modular EF for the VFDO for coxa valga-antiversa deformity correction in DDH. EF is particular useful in proximal femur osteotomy since it permits an intra-operative gradual and adjustable correction of the deformity, whereas the other devices have a predetermined correction angle.

In conclusion, the benefits of EF for VDFO may be resumed in: (1) intra-operative gradual adjustability of the correction; (2) minimal surgical exposure; (3) greater simplicity of the frame than other type of EF; and (4) no need of additional surgery for its removal.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval For this type of study, formal consent is not required.

Informed consent Informed consent was obtained from all individual participants included in the study.

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