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ORIGINAL CLINICAL ARTICLE

Valgus extension femoral osteotomy to treat "hinge abduction" in Perthes' disease

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Abstract
Purpose "Hinge abduction" is a complication of Perthes' disease caused by impingement of the extruded superolateral portion of the femoral head against the lateral lip of the acetabulum. Catterall first described femoral valgus extension osteotomy (VGEO) to treat this condition. We report the results of this operation in 16 cases of Perthes' disease with "hinge abduction".
Methods Sixteen hips in 16 patients affected by Perthes' disease and "hinge abduction" were operated on at a mean age of 10.1 years and followed up an average of 6.5 years later. Before surgery, the mean Iowa hip score was 44.4 points. Preoperative radiographs were taken with the affected hip in maximum adduction in order to calculate the amount of valgus correction. The osteotomy was performed between the greater and the lesser trochanter, and it was fixed with a hip plate.
Results All the osteotomies healed uneventfully. At follow-up, no patient complained of pain and hip abduction ranged from 20° to 45°. Four out of the 16 patients had a moderate limp, and 12 had an improvement in gait pattern compared to preoperatively. At follow-up, the Iowa hip score totaled a mean of 83.6 points, with a statistically significant improvement in comparison to the preoperative evaluation. At follow-up, two hips were classified as Stulberg II–III, ten hips as Stulberg III, and four as Stulberg IV.
Conclusions In our hands, VGEO was an effective procedure to treat "hinge abduction" in severe Perthes' disease with satisfactory results. The main limitation of our study is its short follow-up.

Keywords Perthes' disease · "Hinge abduction" · Valgus extension femoral osteotomy · Stulberg classification

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Introduction

In severe cases of Legg–Calvé–Perthes disease, deformity of the femoral head is likely to occur mainly during the fragmentation stage of the disease. In some cases, the anterolateral osteocartilaginous part of the deformed femoral head protrudes outside the acetabulum, impinging against its lateral lip during hip abduction. As a consequence, the femoral head moves eccentrically instead of concentrically within the acetabulum, with widening of the inferomedial joint space and further reduction of the superolateral joint space. This alteration of the normal hip abduction movement was called "hinge abduction" about 30 years ago by Grossbard [1] and Catterall [2]. The clinical consequences of "hinge abduction" may be: (a) increasing hip pain; (b) restriction of hip motion; (c) flexion–adduction contracture of the hip; (d) apparent shortening of the affected limb; (e) limping; (f) ipsilateral genu valgum.

Valgus extension osteotomy (VGEO) was first described by Quain and Catterall [3] as a salvage surgical procedure to fix "hinge abduction" in Perthes' disease. Since then, the literature includes few reports on results obtained with this surgical procedure [4–8], which appears to be rarely performed by pediatric orthopedic surgeons in spite of the relatively high incidence of "hinge abduction". In fact, according to Reinker [9], it affects almost 44 % of the patients with Catterall group 4 Perthes' disease. We report

Table 1 Preoperative and postoperative data on patients treated by valgus extension femoral osteotomy (VGEO). The difference between the Iowa hip score before and after VGEO was statistically significant ($p = 0.0001$)

Case	Gender	Age at surgery (years)	Previous treatment	Herring group at surgery	Iowa hip score at preoperative evaluation (points)	Iowa hip score at follow-up (points)	Length of follow-up (years)	Stulberg class at follow-up
1	F	8.5	Atlanta brace	B/C	58	75	2.5	III
2	M	8.3	Protected weight-bearing, physical therapy	B/C	60	96	3	II–III
3	M	8.6	Atlanta brace	C	46	95	4.1	II–III
4	M	10.2	Protected weight-bearing, physical therapy	C	50	90	4.3	III
5	M	11.1	Atlanta brace	C	36	74	4.8	IV
6	M	12.3	Protected weight-bearing, physical therapy, cheilectomy	C	31	69	5	IV
7	M	9.9	Protected weight-bearing, physical therapy, cheilectomy	C	48	95	5.1	III
8	F	9.8	Protected weight-bearing, physical therapy	C	64	93	5.1	III
9	M	9.6	Protected weight-bearing, physical therapy	C	44	86	6.5	III
10	M	9.2	Atlanta brace	B/C	52	88	7	III
11	M	10.4	Atlanta brace	C	29	78	7.3	III
12	M	11	Protected weight-bearing, physical therapy	C	33	72	8	III
13	M	12.3	Atlanta brace	B/C	38	78	9.3	IV
14	M	8	Protected weight-bearing, physical therapy	C	60	94	10.5	III
15	M	9	Atlanta brace	C	34	86	10.8	III
16	F	13	Varus osteotomy, physical therapy, cheilectomy	C	27	69	11	IV

our experience with VGEO in patients with "hinge abduction" caused by Perthes' disease.

Materials and methods

Seventy-nine consecutive patients with unilateral Perthes' disease classified as either Herring B/C or C were treated at the Department of Orthopaedic Surgery of the University of Rome "Tor Vergata" from 1999 to 2009. Nineteen patients developed "hinge abduction" (24 % of the affected hips), and they were treated by VGEO. "Hinge abduction" was diagnosed according to both clinical and radiographic parameters. All the patients complained of increasing pain and all of them had worsening of the restriction of hip motion, particularly of hip abduction. X-rays showed widening of the inferomedial joint space and further reduction of the superolateral joint space, with extrusion of the lateral part of the femoral epiphysis. Three patients could not be located, while 16 patients accepted the request to come to our hospital for follow-up evaluation. Thirteen patients were male and three were female. The right hip was affected in nine cases and the left in seven. The average age at surgery was 10.2 years (range: 8–13 years) (Table 1). Most of our cases were late presenters of the disease. At the time of surgery, 12 hips were in the late fragmentation stage and four in the healing stage [10]. Two patients were classified Catterall 2, five as Catterall 3, and nine as Catterall 4. Previous treatment consisted of containment with an Atlanta brace in seven patients, cheilectomy after protected weight-bearing with crutches in two patients, varus osteotomy followed by cheilectomy in one patient, and observation and physical therapy to maintain a good range of motion in six patients. During treatment, ten patients also had brief periods of skin traction in bed and non-steroidal anti-inflammatory drugs (NSAIDs) administration (Table 1).

All the patients had preoperative clinical and radiographic evaluations. The clinical evaluation was done using the Iowa hip scale [11], which assigns a maximum of 100

points: 35 for freedom from pain; 35 for function, 10 for gait; 10 for deformity; 10 for range of motion. Because of our patients' young age, item 10 of the Iowa hip scale function part, "Drives a car", was changed to "Rides a bicycle".

The radiographic examination included an anteroposterior view of the pelvis in neutral position and an anteroposterior view of the affected hip in maximum abduction in order to document the "hinge abduction", and in maximum adduction to plain the VGEO (Fig. 1). In some cases with severe "hinge abduction", a computed tomography (CT) scan of the hip was taken. The following radiographic parameters were measured on the standard anteroposterior view of the pelvis (Table 2): (a) femoral neck-shaft angle [12]; (b) Sharp angle [13]; (c) center-edge angle (Wiberg) [14]; (d) lateral femoral subluxation [15]; (e) % acetabular coverage [15]. Hip skeletal maturity was assessed by closure of the triradiate cartilage and proximal femoral physis [16]. We never used arthrography or magnetic resonance (MR), although their use has been recently recommended [17].

Surgery was performed by the senior author (E.I.) or under his supervision. Before surgery, all the patients were put in skin traction for 3–7 days, during which NSAIDs were administered to address hip muscle contracture. The angle of correction was calculated on the basis of the radiographic hip adduction test so as to allow the hip to recover as much abduction as possible in order to equalize abduction of the contralateral normal hip. To fix the osteotomy, a 90° angled blade-plate (Synthes–Mathys) was used until 2007, and, since then, a new hip screw plate with angular stability (Synthes) has been utilized.

The subtrochanteric lateral part of the femur was exposed and prepared to host the stabilization plate in accordance with the angle of correction. A transverse cut was made with an oscillating saw between the greater and

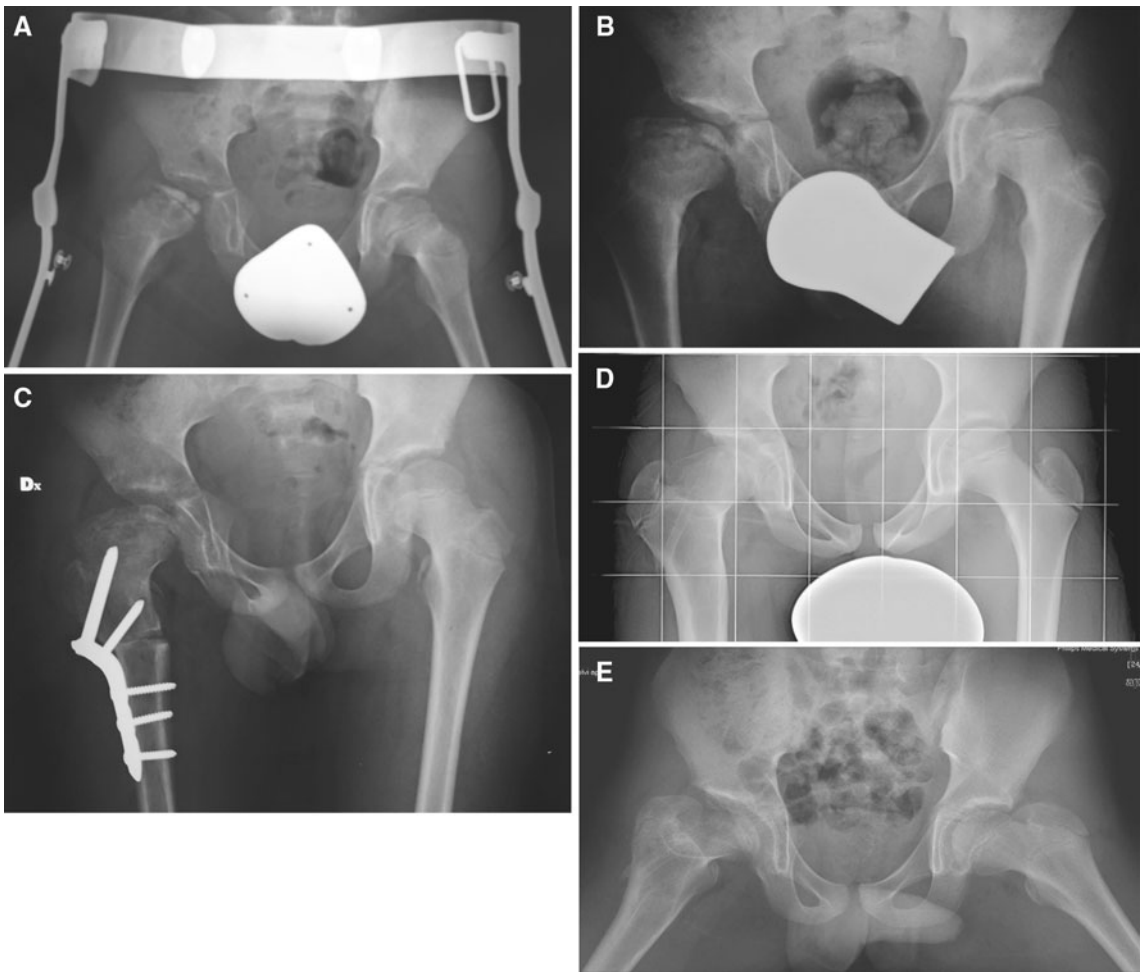

Fig. 1 **a** A 7-year-old boy with right Herring C Perthes' disease treated with an Atlanta brace. **b** A year and a half later, severe flattening of the femoral head was present with "hinge abduction". **c** Six weeks after valgus extension femoral osteotomy (VGEO) of the affected hip. **d** Four years later, the neck-shaft angle measured 140°, the boy had resumed full sport activity, and the range of motion of the hip showed only 10° limitation of internal rotation . **e** Maximum hip abduction was measured to be 40° on the right and 43° on the left (normal) side. The hip was still remodeling, and it was classified as Stulberg II–III. Case 3 in Table 1

Table 2 Radiographic measurements before surgery, after surgery, and at follow-up

	Preoperative	After surgery (2–5 months)	Follow-up	Normal side	*p*-value*
Neck-shaft angle	128° (100°–136°)	142° (128°–160°)	140° (130°–155°)	140° (135°–145°)	0.000
Sharp angle	43° (42°–46°)	43° (40°–46°)	41° (40°–44°)	41° (38°–44°)	Non-significant
Center-edge angle (Wiberg)	31° (10°–46°)	36° (18°–46°)	46° (32°–50°)	43° (40°–46°)	0.000
Lateral femoral subluxation	3.1 (2–5)	2.2 (1–3.3)	1.4 (0–3.3)		0.000
% acetabular coverage	20.6 % (0–35 %)	19.5 % (0–38 %)	13.2 % (0–25 %)		0.029

* Between preoperative and follow-up values

lesser trochanter and completed with an osteotome. The plate was tightly secured to the proximal fragment by either a blade or screws and then levered down with a bone-holding forceps and fixed to the femoral shaft by cortical screws. Soft tissue releases were never performed, owing to full muscle relaxation obtained by both preoperative traction and general anesthesia. Postoperatively, the patients had early mobilization in bed and were allowed toe-touch weight-bearing after 5–7 days depending on pain, with the use of crutches. Physical therapy based on hip joint range of motion was started about 10 days after surgery; continuous passive motion (CPM) was never used. Full weight-bearing was allowed at 3–4 months instead of 6 weeks, which is sufficient time for the osteotomy to heal, because we were afraid of causing deterioration of the shape of the femoral head that was still in the fragmentation stage in most of our patients.

At follow-up, all the patients had both clinical and radiological evaluations according to the same preoperative criteria, except for the anteroposterior view in maximum adduction (Fig. 1). Whenever lower limb length discrepancy was suspected, clinical measurements were taken from the anterior superior iliac spine to the tip of the medial malleolus, whereas radiographic measurement was taken to evaluate more precisely the amount of leg length discrepancy on standing radiographs of the pelvis and the lower limbs. All the hips were classified radiographically at follow-up according to Stulberg et al. [16]. For the statistical analysis, the data from every subject were collected in a database (Excel) and then switched to the software program SPSS (Statistical Package for the Social Sciences). Comparison tests were conducted with analysis of variance (ANOVA) for sequential measures or the *t*-test for data from two groups; Bonferroni correction was used to compare data from more than two groups. A *p*-value of <0.05 was considered to be significant.

Results

The average age at follow-up was 17.4 years (range: 10.5–24 years). The average length of follow-up was 6.5 years (range: 2.5–11 years) (Table 1). Before the operation, all the patients complained of pain. At the last follow-up examination, 13 patients were completely pain-free, and some of them were taking part in sporting activities. The other three patients had occasional pain in the groin or thigh after prolonged walking or strenuous activities.

The overall range of motion of the hip had improved in all the patients. All the patients were satisfied with their range of motion and the ability to engage in activities of daily living. Hip abduction had improved from a mean of 5° (range: −15°–10°) before surgery to a mean of 35° (range: 5°–50°) at the last follow-up.

All the patients were limping before the operation. Antalgic limp, short-leg limp, and flexed–adducted hip gait were variously associated and represented. At the last follow-up examination, 12 patients had improvement in gait pattern compared to preoperatively, whereas four were still limping. In two of these patients, the gait alteration was very mild, and it was caused by hip abductor weakness. The other two patients still showed some hip flexion gait, although it had markedly improved after surgery, because they lacked hip extension movements.

The overall increase of the Iowa hip score from before surgery to the latest follow-up examination averaged almost 40 points, and the difference was statistically significant ($p = 0.0001$) (Table 1).

Measurements of the radiological parameters before surgery and at follow-up are reported in Table 2.

The mean femoral neck-shaft angle was 128° before surgery and 140° at follow-up; the difference was statistically significant ($p = 0.000$). The Sharp angle decreased from a mean of 43° to a mean of 41°, but the difference was not statistically significant. The center-edge angle of Wiberg increased from a mean of 31° before the operation to a mean of 46° after the operation, and the difference was statistically significant ($p = 0.000$). The lateral femoral subluxation decreased from 3.1 to 1.4 and the percentage of acetabular uncoverage from 20.6 to 13.2 %. Both differences were statistically significant ($p = 0.000$; $p = 0.029$). No statistical correlation was found between the increase of abduction and the radiological correction of the neck-shaft

angle. In 12 patients, both the triradiate cartilage and proximal femoral physis were closed, while in four patients, they were still open. In the nine patients who were fully grown at follow-up, lower limb length discrepancy ranged from 0.5 to 1.5 cm.

The final Stulberg classification was class III in ten hips and class IV in four hips, while in two hips which had open physes at the time of the last follow-up examination, an intermediate rating of class II–III was given because the medial part of the femoral epiphyses was round and the lateral part was elliptical. In general, the hips operated during the fragmentation stage were at the end of that stage, and, in particular, the medial part of the epiphysis, which was put under increased weight-bearing after the osteotomy, showed almost completed radiographic healing. Furthermore, in no case did we observe after surgery further collapse of the femoral head (Table 1; Fig. 1), although VGEO reduces the containment of the femoral head.

In two patients with severe flexion–adduction contracture of the hip and limping, genu valgum deformity developed on the affected side. In one patient, the deformity was corrected with medial eight-plate epiphysiodesis only, while in the other patient, who was close to physeal closure, a supracondylar open-wedge femoral osteotomy was also performed and fixed with a plate. In those cases, we could have obtained better results by dividing psoas and adductors. Hardware was removed only in children with open physis, from 8 to 12 months after surgery.

Discussion

The radiographic and clinical evolution of Legg–Calvé–Perthes disease is variable: both age at diagnosis and the amount and location of femoral head involvement seem to be the most important prognostic factors [18–20]. In severe cases, a limited number of patients with Perthes' disease may develop "hinge abduction" with lateral extrusion of the deformed femoral head during the course of the disease. The prevalence of "hinge abduction" has been reported as ranging from 5.3 to 12 % in large series of Perthes' disease, regardless of the degree of severity of the disease; however, the prevalence rises to 44 % in Catterall group 4 hips [9] and accounted for 24 % in Herring group B/C and C hips of our series.

Both arthrography and 3D CT scans have been proposed as precise diagnostic imaging techniques to assess "hinge abduction" of the hip in Perthes' disease [3, 7, 9, 21]. However, in our series, standard anteroposterior radiographs in both neutral and maximum hip abduction were sufficient to demonstrate "hip hinging", as previously reported [7].

Various nonsurgical and surgical procedures have been described to treat patients with "hinge abduction" in Perthes' disease. Reinker [9] reported good results with bed rest and progressive traction in abduction for several weeks, followed by Petrie cast and/or various surgical procedures, including varus femoral osteotomy and Chiari osteotomy. Traction for several weeks followed by shelf acetabuloplasty has been recommended by others [22]. Pelvic procedures like acetabuloplasty [23] and either innominate or triple pelvic osteotomy [24, 25] may provide very good femoral head containment in Herring B/C or C hips. However, the presence of a marked deformity in the lateral extruded portion of the femoral head (either severe flattening or indentation) may require a salvage procedure such as VGEO. Cheilectomy has been recommended by other authors to remove the extruded portion of the femoral head [26, 27]. We performed cheilectomy in three of our cases, with worsening of hip stiffness and no improvement of abduction.

VGEO, first described about 25 years ago by Quain and Catterall [3] to treat "hinge abduction", has not, since then, been extensively popularized. We were able to find only a few reports in the English literature describing VGEO as a salvage procedure to cure "hinge abduction" as a complication of Perthes' disease [3–8, 21]. Including the classic series of Catterall et al., less than 150 hips with "hinge abduction" caused by Perthes' disease and treated by VGEO have been reported so far, with pain relief and improved range of motion of the hip ranging from 80 to 100 % [3–8].

One of the most rewarding clinical effects of VGEO was the complete disappearance of pain in 85 % of the patients of our series. In addition, the whole range of motion of the affected hip showed an average improvement of abduction from 5° before surgery to 35° after surgery. The increase of hip abduction after VGEO seems to be connected with the new relationship between the femoral head and the acetabulum, rather than to the overall increase of the neck-shaft angle. In none of our cases was soft tissue release combined with the index procedure. Immediately after surgery, we were always successful when we tried to abduct the hip under general anesthesia, and adductor contracture spontaneously resolved during the postoperative days.

Residual limping was present at follow-up in four of our 16 patients. Two of them—who had presented marked limping due to apparent leg shortening caused by fixed hip adduction before surgery—had some mild limping due to hip abductor weakness. In the two other patients—who had presented a marked limp due to fixed hip flexion–adduction contracture and knee valgus deformity—limping was improved by surgery, but it was still present at follow-up in spite of limb length equalization, mechanical axis correction of the affected lower limb, and improvement of hip

abduction to 20°. Lack of hip extension due to residual joint incongruency might have been one of the main reasons for limping in those cases.

At follow-up, the radiographic examination showed that the valgus redirection of the neck-shaft angle was maintained, although it was a little decreased, as already described by others [5]. In most of our cases belonging to Herring B/C or C groups before the operation, the valgus position of the femoral head had a beneficial effect on the subsequent improvement of hip abduction by laterally displacing the deformed portion of the femoral head away from the acetabular rim, as shown by postoperative radiographs. In fact, most cases ended up in Stulberg class III, two in class II–III, and only the more mature hips that had lost their remodeling potential ended up in class IV.

Joseph [28] reported that the acetabulum's width increases in proportion to the widening of the femoral head, and the acetabular radiographic indices are altered accordingly. The acetabular inclination slightly decreased from surgery to follow-up, as shown by the Sharp angle value, whereas acetabular uncoverage of the femoral head and lateral femoral subluxation improved over time, partly due to the better relationship of the round portion of the femoral head with the acetabulum and partly due to the gradual resorption of the extruded flat portion of the femoral head which no longer articulated with the acetabulum. In some cases, residual acetabular dysplasia, as shown by Sharp angle >42°, with femoral head uncoverage were still present at follow-up. Probably, some acetabular procedure might be needed in the future in those cases.

Knee valgus deformity was present in two cases who had been limping for several months with the hip fixed in flexion–adduction. Knee valgus deformity has already been described as a Perthes' disease complication [29], but it must be corrected to improve gait after correction of the flexion–adduction hip contracture by VGEO of the proximal femur, as we did in two of our patients.

In conclusion, we believe that VGEO can be an alternative as a salvage procedure in given cases of Perthes' disease with "hinge abduction" when containment with spherical congruity cannot be obtained via other established methods [23–25]. The main limitations of our study are the fact that it is a retrospective study, the non-objective sphericity evaluation of the femoral head, the lack of long-term follow-up to skeletal maturity in some cases, and its short follow-up.

Conflict of interest None.

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