

Case report

Mechanical failure of external fixator during hip joint distraction for Perthes disease

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Introduction

Legg-Calve-Perthes (Perthes) disease is a pediatric disorder of the hip joint of unknown etiology, predominantly affecting young boys ages 4–10 years. The disorder is characterized by an insidious onset of necrosis with fragmentation and collapse of the proximal femoral epiphyses followed by reossification and repair.^{1,2} Subchondral fracture and collapse of the femoral head can occur during the repair process.^{1,2} In severe cases, flattening of the femoral head with joint incongruity can lead to “hinged abduction”² and premature osteoarthritis of the hip.^{3,4} For these high-risk patients, a variety of surgical treatment methods have been proposed with the hope of restoring articular congruity and thus delaying onset of arthritis and loss of hip joint mobility.^{2,5} Results of traditional techniques such as bed rest, containment treatment using a hip abduction brace or Petrie cast, and femoral or acetabular osteotomy have been mixed.^{2,5} More recently, the technique of articulated joint distraction or arthrodiastasis using an external fixator has been utilized to achieve controlled distraction across the hip joint.^{6–9} The goal of such treatment is prevention of femoral head flattening while maintaining mobility of the involved hip joint. Early reports have been encouraging,^{6–9} but there is limited information about the surgical pitfalls and complications associated with this technique.

The purpose of this study is to report a case of mechanical failure of a monolateral external fixator during arthrodiastasis treatment in a child with severe Perthes disease. The specific mode of failure, a method to correct this problem, and possible preventive measures are discussed. Our patient’s family was informed that data concerning the case would be submitted for publication.

Case report

An 8-year-old boy presented with a 7-month history of insidious onset of left groin discomfort and a limp. There was no history of any trauma or systemic illness including sickle cell disease. Clinical examination revealed a thinly built, healthy-appearing child with an antalgic gait and 1.5 cm shortening of the left lower extremity. The range of motion of the hips revealed limited flexion of 85° on the left side compared to 135° on the right side. He had a 15° fixed flexion deformity of the involved hip. He had no internal rotation compared to 30° on the right side, and external rotation was 5° on the left and 55° on the right side. Hip abduction was 5° on the left and 45° on the right side.

Radiographs, including an anteroposterior (AP) view of the pelvis (Fig. 1) and a lateral view of the hips, revealed total head involvement of the left hip consistent with a diagnosis of Perthes disease. In addition to more than 50% collapse of the lateral pillar (Herring type C),¹⁰ this patient had other radiographic signs, including lateral extrusion of the epiphysis, metaphyseal cyst, horizontal appearance of proximal femoral physis, a break in Shenton’s line, lateral subluxation of the hip, and possible hinged abduction, suggesting a poor prognosis.

A trial of outpatient physical therapy and a home exercise program failed to alleviate his symptoms and the clinical findings. A hip arthrogram revealed flattening of the superolateral portion of the femoral head with proximal migration of the femur.

The patient underwent adductor tenotomy and application of a previously unused EBI (Parsipanny, NJ, USA) hinged external fixator (Fig. 2) for arthrodiastasis. Three hydroxyapatite-coated pins were placed in the supraacetabular area and two in the femoral shaft. The uniplanar hinge was placed at the level of the center of the femoral head, and the left lower extremity was kept in approximately 15° of abduction and 10° of inter-

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nal rotation. Acute distraction (5 mm) at the fixator was carried out under general anesthesia. Satisfactory placement of the external fixator and free mobility of the hip in the flexion-extension arc were confirmed intraoperatively (Fig. 3). All connectors and bolts were firmly hand-tightened with a wrench, based on the manufac-

turer's recommendation.¹¹ The patient was discharged home the following day with instructions for no weight bearing on the affected extremity.

Outpatient physical therapy, including flexion and extension range of motion exercises of the left hip, was initiated. The patient's family was instructed to start



Fig. 1. Preoperative anteroposterior (AP) radiograph of the pelvis showing total head involvement of the left hip with metaphyseal cysts and lateral subluxation secondary to Perthes disease in an 8-year-old boy

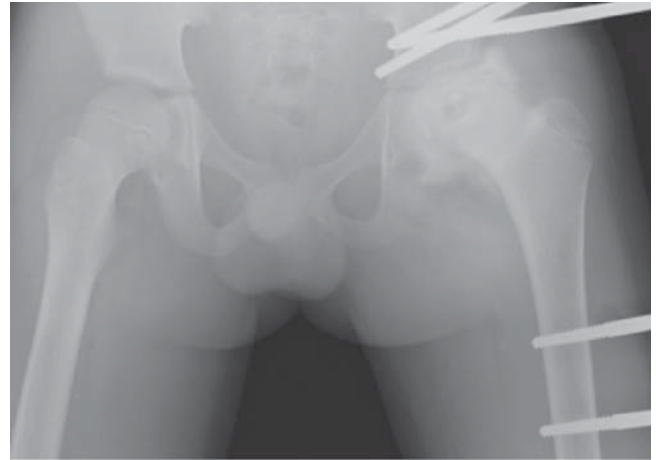


Fig. 2. Immediate postoperative radiograph following a hip arthrogram, adductor tenotomy, and placement of a monolateral hinged external fixator for arthrodiastasis across the hip joint. Note the mild abduction positioning of the left lower extremity

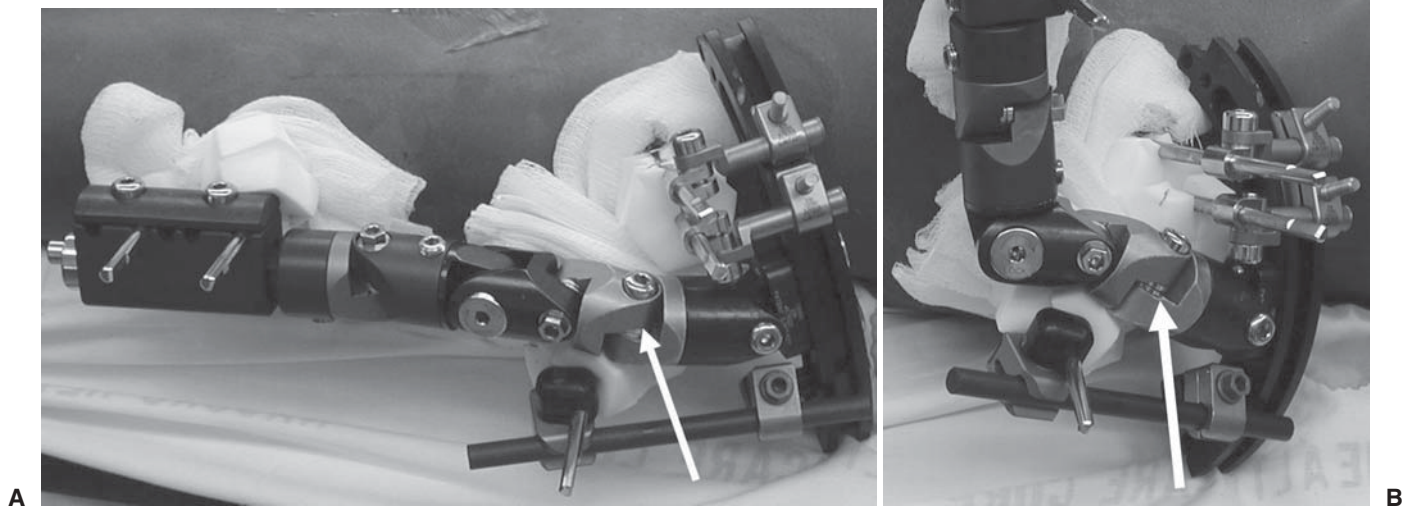


Fig. 3. Clinical photograph of the hinged external fixator, allowing passive extension (A) and flexion (B) of the hip joint. The arrow indicates the dual locking connector between the pelvic and femoral portions of the fixator

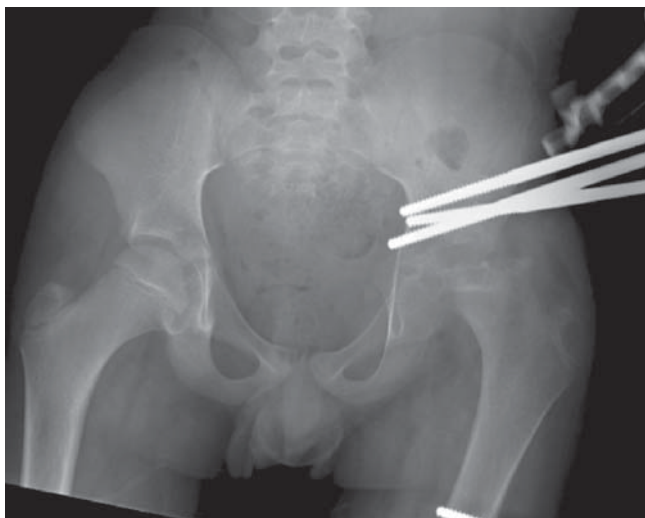


Fig. 4. Follow-up radiograph 6 weeks postoperatively demonstrating an adduction deformity of the left lower extremity with no significant distraction at the hip joint

distraction at the rate of 1 mm a day in two installments, starting the third day following surgery. The goal of distraction was slight overcorrection of the break in Shenton's line, as seen on the AP radiograph of the hip.

Two weeks later, the AP radiograph of the left hip revealed a persistent break in Shenton's line. The family was instructed to continue distraction at the same rate. The patient was compliant with physical therapy and non-weight-bearing instructions. Approximately 6 weeks postoperatively, despite several millimeters of distraction of the external fixator, Shenton's line remained disrupted on radiographs, and the left lower extremity was noted to be in 15° of adduction (Fig. 4). Pin sites were dry and clean with no change in position of the half-pins on radiographs. Loss of serrations of the large bolt connecting the pelvic and femoral portions of the external fixator was noted (Fig. 5). This mechanical failure of the external fixator had allowed the left leg to adduct at the hip.

An examination was performed under anesthesia, and the left lower extremity was repositioned in 15° of abduction and 10° of internal rotation. Improved seating of the femoral head was confirmed with an arthrogram, and the dual locking connector and bolt between the pelvic and femoral segments were replaced and cemented with polymethylmethacrylate (PMMA) (Fig. 6). Acute distraction (15 mm) was performed under anesthesia, and adequate repositioning of the femoral head with restoration of Shenton's line was achieved. No further distraction was done post-operatively, and the physical therapy regimen was reinstated.

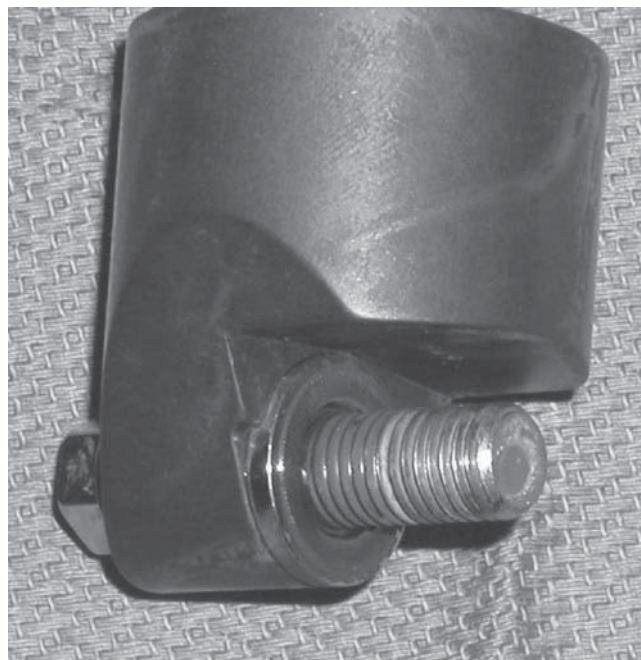


Fig. 5. Retrieved dual locking connector, demonstrating loss of serrations and damage to the threads of the connector bolt

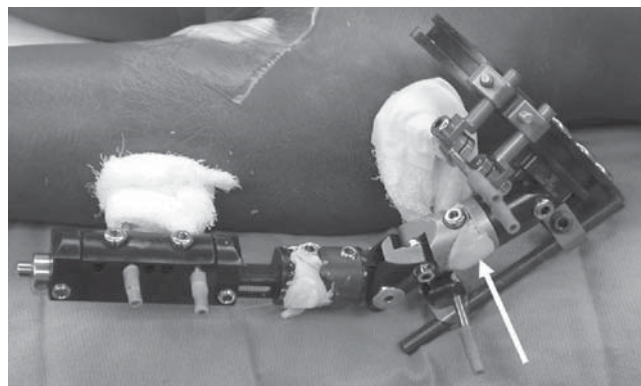


Fig. 6. Intraoperative photograph following revision of the external fixator with polymethylmethacrylate (PMMA) supplementation at the dual locking connector (*arrow*)

Follow-up radiographs showed no further change in the position of the hip. Eight weeks following fixator adjustment, the patient was brought back to the operating room. A left hip arthrogram revealed restoration of Shenton's line with residual flattening of the weight-bearing portion of the femoral head. The external fixator was removed. Under general anesthesia, left hip abduction was noted to be 35°. The patient was placed in a customized hinged hip abduction orthosis, and his weight-bearing status was gradually advanced with physical therapy.



Fig. 7. Final AP pelvis radiograph of the patient in the remodeling phase, showing evidence of persistent flattening of the femoral head and mild superolateral hip subluxation

On a recent examination, done 2 years postoperatively, hip flexion was 95° on the left and 130° on the right; abduction was 20° compared to 50°; external rotation was 15° compared to 60°; and internal rotation was 15° compared to 30°, respectively. He has remained asymptomatic and resumed regular activities despite a mild abductor lurch on the affected left side. Follow-up radiographs reveal slight disruption of Shenton's line, although it had improved compared to the preoperative imaging studies. Reossification of the femoral head with residual flattening was noted (Fig. 7). A scanogram revealed 5-mm leg-length discrepancy, with the left side being shorter.

Discussion

Articulated joint distraction treatment has been reported for various stages of osteoarthritis and chondrolysis affecting a variety of joints including the hip.¹²⁻¹⁴ Unlike femoral and pelvic osteotomies, arthrodiastasis treatment is minimally invasive, does not involve any iatrogenic alteration of the local bony anatomy, and avoids cast immobilization. During joint distraction treatment for Perthes disease, the goal of treatment is to improve hip mobility and favorably alter the natural history. This is likely accomplished by reducing the mechanical stresses across the hip joint, which may facilitate cartilage proliferation and endochondral ossification of the proximal femoral epiphysis.^{13,14} It appears to be a viable surgical alternative in older children who would otherwise have a high likelihood of poor radiographic and functional outcome.²

Few authors have reported adverse events other than pin-tract infections related to arthrodiastasis treatment.^{6-8,12} Maxwell et al.,⁸ using the Orthofix external fixator, reported two patients who had advanced col-

lapse of the femoral head secondary to Perthes disease and sustained pin breakage. Although no firm recommendations were made, they suggested that advanced age and weight should be further investigated as a potential cause for this failure, as these factors may influence the amount of force that can be safely tolerated by the external fixator pins. Segev et al.⁹ reported on 16 patients with late-onset severe Perthes disease who were treated with arthrodiastasis in combination with limited soft tissue release. They mentioned that one clamp broke during treatment and required replacement. However, no details of the cause or potential preventive measures were provided. Interestingly, none of the potential factors that can contribute to hardware failure, such as obesity, application of a previously used external fixator, noncompliance with weight-bearing status, or attempts at forceful hip abduction-adduction exercises, was present in our patient.

Although no study has measured the forces generated during joint distraction, few investigators have tried to measure them during limb lengthening. Simpson et al.,¹⁵ using precalibrated load cells incorporated into the lengthening mechanism of monolateral external fixators, reported generation of axial forces of 300–1000N in patients undergoing femoral lengthening. Angular deformity at the osteotomy site and mechanical failure of the external fixator was noted in some patients with congenital shortening, who also demonstrated the highest axial forces. They cautioned that with the high distraction forces recorded during limb lengthening safe levels for many unilateral fixators might be exceeded. Younger et al.¹⁶ found similar values for axial forces on the external fixator frame in their analysis of three patients undergoing femoral lengthening.

Chao and Hein¹⁷ performed mechanical testing on the Orthofix (Verona, Italy) external fixator and found that the cam positioning of the ball joint gradually migrated as the forces were incrementally increased. Repetitive manual tightening and loosening of the ball joint caused abrasive wear on the cam and bushing surfaces. Modification of the fixator design was recommended to improve its mechanical performance. Moroz et al.¹⁸ also reported on mechanical testing of the Orthofix device and found the ball joint to be the most common site of mechanical failure. Marsh et al.¹⁹ reported on the use of the Orthofix external fixator for treatment of adult supracondylar femur fractures. They encountered similar failures at the ball joint and suggested reinforcement with PMMA.

Dirschl and Obremsky²⁰ reported on mechanical testing of previously used monolateral external fixators and compared their mechanical strength with previously unused fixators. They found that a mean load 721 ± 70N caused failure of previously used standard fixators, which was not significantly different from the 749

± 81 N for the unused fixators. However, they did report major damage in 14% of the 120 serrated joints tested, and the remaining 86% of the serrated joints also exhibited minor damage. The damage included deformation or loss of material across serrations, which resulted in the removed material being forced into the trough between the teeth, limiting complete interdigitation of the components. This mode of failure and findings at the serrated joints are similar to observations seen in our case. We were unable to find a biomechanical study reporting on the increased load to failure following reinforcement with PMMA of either a ball joint or dual locking connector of an external fixator.

The treating surgeon must be aware of mechanical failure as a potential cause for lack of anticipated hip joint distraction during arthrodiastasis treatment for Perthes disease. There is a lack of biomechanical studies investigating the forces generated at the external fixator during articulated hip joint distraction and whether use of PMMA decreases such forces at the various connectors of the external fixator. Based on the information available, we recommend routine cementing of the dual locking connector mechanism or ball joints of monolateral external fixators in patients who undergo articulated joint distraction of the hip.

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