Percutaneous osteotomy for deformity correction in adolescents with severe slipped capital femoral epiphysis

Sanjeev Sabharwal, Rahul Mittal and Caixia Zhao

Various methods of performing proximal femoral realignment in adolescents with severe slipped capital femoral epiphysis exist. We report the technique and early results of a percutaneous, opening wedge subtrochanteric femoral osteotomy using an external fixator for correcting multiplanar deformities in such patients. Nine adolescents with severe slipped capital femoral epiphysis underwent a percutaneous osteotomy at an average age of 14.5 years. Mean operative blood loss was 61 ml, with 2 days of inpatient stay and 129 days of external fixation time. At an average follow-up of 23 months, hip flexion improved from 74 to 106°, internal rotation from −5 to +17°, external rotation from 71 to 41° and abduction from 29 to 36°. Radiographs revealed an improvement in anteroposterior head shaft angle from 112 to 134° and lateral head shaft angle from 72 to 15°. One patient had transient chondrolysis. No fixation-related problems, deep infection, avascular necrosis or refracture occurred. On the basis of our preliminary results, this percutaneous technique offers several advantages over currently available methods for surgical correction of severe slipped capital femoral epiphysis deformities. ***J Pediatr Orthop B*** **15:396–403 © 2006 Lippincott Williams & Wilkins.**

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Introduction

The natural history of slipped capital femoral epiphyses (SCFE) suggests that hips with greater severity of deformity have a worse prognosis with early onset of degenerative arthritis [1]. This predisposition for premature arthritis is probably due to altered biomechanics and femoro-acetabular impingement [2,3]. Various methods of proximal femoral realignment have been used to address the underlying deformity [4] with the goal of improving symptoms, function and longevity of the hip joint. Although a more anatomical correction can be obtained with a femoral neck osteotomy, there is an increased risk of avascular necrosis of the femoral head [5,6]. Thus, some authors have recommended that the osteotomy be performed further away from the proximal femoral growth, at or just distal to the lesser trochanter [6–11].

Drawbacks with the current techniques of subtrochanteric osteotomies for SCFE in typically obese patients include excessive blood loss [8,9], deep infection [7–11], delayed union [8,9] and further shortening of the extremity owing to a closing wedge correction [7–11], Moreover, there are implant-related issues such as technical difficulty with device insertion, limited ability to make adjustments in the angular correction following rigid internal fixation, and inadequate fixation [9,10] with occasional need for supplemental spica cast immobilization [8,9,11].

Achieving correction of limb deformities through less invasive means is becoming increasingly popular [12]. Recently, satisfactory results were reported in children with developmental coxa vara using a percutaneous femoral osteotomy with external fixation [13]. Since 2000, we have used a percutaneous osteotomy with external fixation for correcting multiplanar deformities associated with severe SCFE in adolescents. In this study, we describe the surgical technique and analyze our initial results of a consecutive series of patients who underwent this procedure.

Materials and methods

After Institutional Review Board approval, the medical records and radiographs of all patients with a diagnosis of SCFE who underwent a proximal femoral osteotomy with external fixation were reviewed. A percutaneous opening wedge proximal femoral osteotomy [14,15] with application of a low profile Ilizarov external fixator (Smith & Nephew Richards, Memphis, Tennessee, USA) was performed by or under the direct supervision of the senior author (S.S.).

The indication for the femoral osteotomy was pain and limp in all patients. Clinical evaluation included assessment of pain, function, limp and passive range of hip motion preoperatively and at latest follow-up (Table 1 [11]). Bilateral hip rotation was assessed by a single observer, with the patient in the prone position. The range of motion data in the Southwick scoring system was based on changes in hip motion in any individual plane. For example, if a patient had a loss of abduction of 50° compared with the unaffected hip, and the range of

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Table 1 Southwick's scoring system

Rating scale	Pain	Function	Limp	Range of motion (ROM)	Radiograph
Excellent	None	No limitations	No limp; Trendelenburg not present	ROM within 20° of normal in each plane	No significant incongruity, head-shaft angles within 20° of normal
Good	No pain with activity, minimal with weather change	Walk at least 1 mile	Trace of limp; Trendelenburg not present	ROM within 40° of normal in each plane	Congruous joint, head-shaft angles within 40° of the normal
Fair	Minimal with activity and weather change	Walk at least 1/4 mile	Moderate limp; Trendelenburg not present	ROM within 60° of normal in each plane	Moderate narrowing or incongruity, no avascular necrosis
Poor	Severe disabling pain	Significant limitation, cannot do light work	Severe limp; Trendelenburg present	Greater than 60° degrees loss of ROM in any individual plane compared with normal	Avascular necrosis or severe incongruity

Adapted from [11].

motion was within 20° of the opposite side for all other planes, that patient was given a 'fair' grade for the 'range of motion' category, based on the worst result in any individual plane. Standard radiographs were taken preoperatively and postoperatively including an anteroposterior view of the pelvis and frog lateral of both hips to measure the anteroposterior and lateral head shaft angles [11]. On the basis of clinical and radiographic evaluation, the Southwick score (Table 1) was calculated preoperatively and at latest follow-up. A scanogram was used to measure leg-length discrepancy.

Data were analyzed using the statistical package SAS, version 9.1 (SAS Institute Inc., Cary, North Carolina, USA). Differences in clinical and radiographic outcome between the preoperative and follow-up measurements were compared using the paired *t*-test. The α level for the analysis was set at $P < 0.05$.

Operative technique

After induction of general anesthesia, the patient is positioned supine on the radiolucent Jackson table (OSI, Union City, California, USA) with a folded sheet placed under the sacrum. The involved lower extremity is free draped. On the basis of the preoperative findings, the affected limb is positioned in a 'hip neutral' position with appropriate adduction, extension and external rotation of the affected hip. This is confirmed by visualizing a close to normal appearance of the femoral head with an anteroposterior fluoroscopic view centered on the hip joint. Placing the half pins in the proximal segment with the limb in this position avoids the need for extensive skin and soft-tissue releases around the half pins following the corrective osteotomy (Fig. 1a). With the limb in the hip neutral position, a temporary 1.8-mm Ilizarov wire is placed from the tip of the greater trochanter directed towards the center of the femoral head (Fig. 2a). A 4.8-mm calibrated drill bit is used to drill a hole from the base of the greater trochanter to just above the lesser trochanter, parallel and distal to the above reference wire. A 6-mm hydroxyapatite coated half pin is placed in the path of this predrilled hole (Fig. 2b) and the reference wire is removed. This half pin is intended to simulate the mechanical lateral proximal femoral angle, which is 90° to the mechanical axis of the femur [15,16] (Fig. 2c). The previously placed cannulated screw for in-situ pinning does not need to be removed as it is not in the trajectory of the proximal half pins. A 90° or 120° Ilizarov femoral arch (Smith & Nephew Richards) is mounted on to the half pin with a pin fixation bolt. Care is taken to allow at least a two fingerbreadth space between the arch and the underlying skin. One needs to ascertain adequate soft-tissue clearance without impingement of the femoral arch against the lower abdomen and posterior thigh, allowing for comfortable sitting and lying down, respectively. The proper orientation of the arch to the proximal fragment is spatially similar to how one would place the chisel of a 90° blade plate in relation to the femoral neck (Fig. 1b). This orientation of the arch will line it up orthogonal to the proximal femoral segment. Next, with the patella pointing towards the ceiling, that is, 'knee neutral' position, a half pin is placed essentially at right angles to the femoral shaft, aiming to be slightly (about 7°) more proximal medially, in order to stay at right angle to the mechanical axis of the femur [16] (Fig. 2c). An appropriate-sized femoral arch is mounted onto this half pin (Fig. 1b). A second half pin is added to both the proximal and distal arch while maintaining orthogonal alignment of each arch to the respective bony segment.

A 2-cm longitudinal incision is made between the two arches at the proposed osteotomy site, just distal to the lesser trochanter. Minimal subperiosteal dissection of the lateral cortex is carried out at this level. Under fluoroscopic control, a 4.8-mm drill bit is used to create one or two drill holes of the lateral (near) cortex. The drill bit is directed anteriorly and posteriorly to create multiple perforations of the medial (far) cortex, keeping the trajectory of the drill bit at right angles to the proximal femoral shaft. The osteotomy is completed percutaneously by connecting the drill holes with 0.25 and 0.5-inch osteotomes. Appropriate internal rotation, anterolateral translation, abduction and flexion of the

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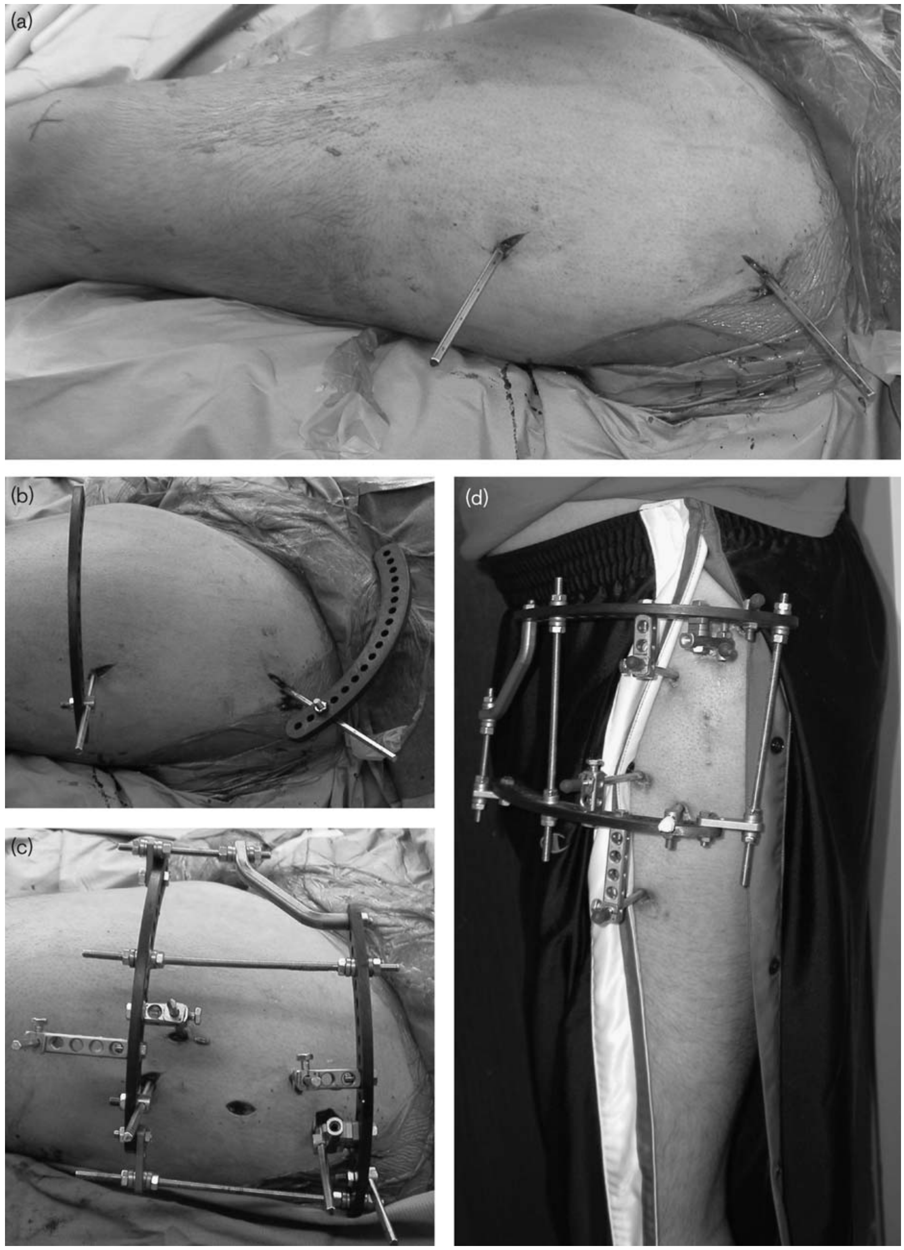
Fig. 1



(a) Intraoperative placement of proximal and distal reference half pins. Note the direction of incisions used for pin placement to allow excursion of the pins following osteotomy correction, minimizing tenting the adjacent skin and soft tissues and need for extensive 'skin releases'. (b) Placement of proximal and distal femoral arches orthogonal to the proximal and distal femoral segments. (c) Appearance of the construct following correction of the multiplanar femoral deformity. Note the near-parallel position of the two arches, use of conical washers on either end of the threaded rods and size of skin incision between the two arches used to perform the percutaneous osteotomy. (d) Appearance of the fixator in the early postoperative course following osteotomy.

distal fragment is carried out in that order, bringing the proximal and distal arches essentially parallel to each other. The anterolateral edge of the proximal fragment is wedged into the intramedullary canal of the distal fragment, thus providing intrinsic stability at the osteotomy site (Fig. 3). The arches are then connected with three evenly spaced threaded rods and conical washers (Fig. 1c). The final alignment of this opening wedge osteotomy is confirmed with biplanar fluoroscopy and can be further adjusted in all three planes with differential compression and distraction of the threaded rods, allowed by the conical washers. In larger patients, or if there are concerns regarding stability of the construct, a third half pin can be added to either one or both femoral

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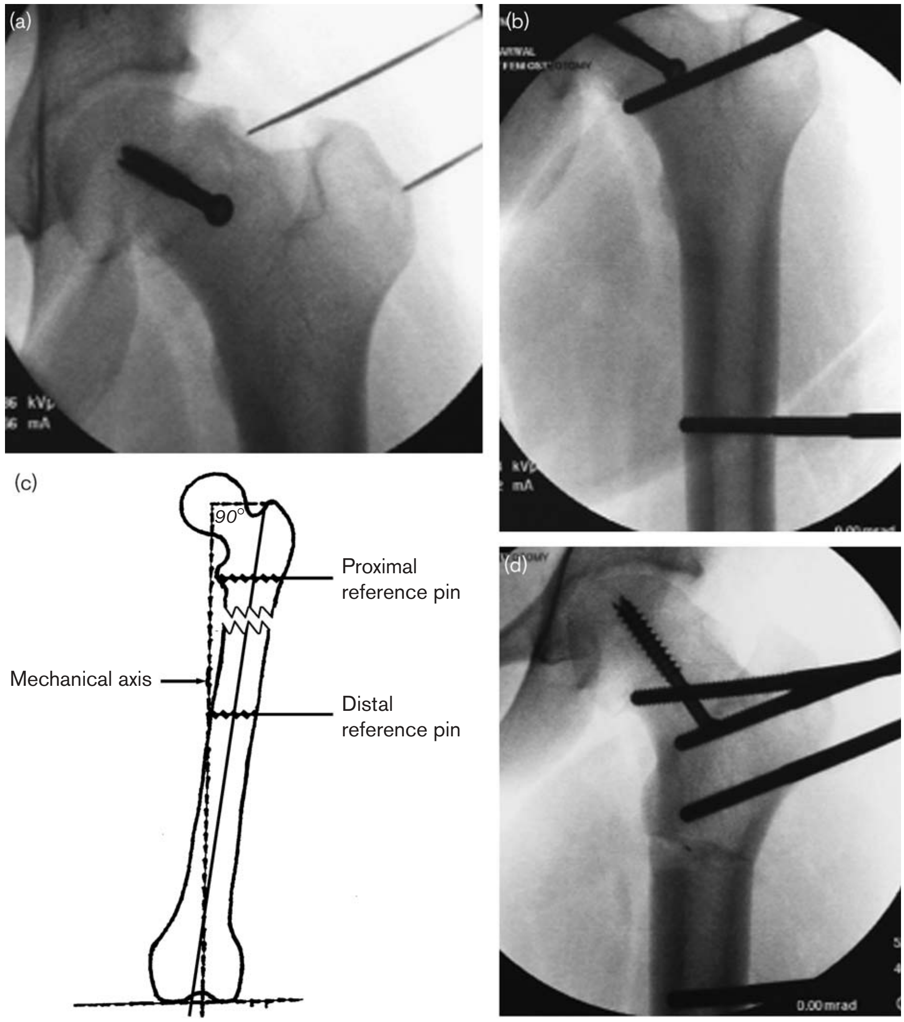
Fig. 2



(a) Anteroposterior fluoroscopic images demonstrating placement of a temporary proximal Ilizarov wire at the tip of the greater trochanter, while the second wire is used to feel the underlying bone, marking the point of insertion of the proximal half pin. (b) Placement of the proximal and distal reference half pins. (c) Guide for pin insertion referenced off the mechanical axis of the femur. Population average mechanical lateral proximal femoral angle (LPFA-m) of 90° is used. The proximal reference pin is inserted parallel and distal to the line between the tip of the greater trochanter and center of the femoral head. Distal reference pin is also at right angles to the mechanical axis. Given the 7° difference between the anatomic and mechanical axis of the femur, this pin is angled slightly distal (about 7°) to the mid-axis of the femoral shaft. (Adapted with permission from [16].) (d) Anteroposterior view demonstrating improvement in the anteroposterior head-shaft angle following completion of the percutaneous osteotomy.

arches (Fig. 2d). If there is any tenting of the skin around the half pins, skin releases are carried out. The small skin incision for the osteotomy is closed with absorbable sutures and an occlusive dressing applied. Typically, the patient is allowed partial weight bearing for the first 4 weeks and then advanced to full weight bearing without any walking aids (Fig. 1d). Although range of hip and knee motion is encouraged, no formal physical therapy is typically provided while the fixator is in place.

Results

Nine consecutive patients (four male and five female) with nine affected hips underwent percutaneous femoral osteotomy. Four black, four Hispanic and one Caucasian patient comprised the study participants. The average age at surgery was 14.5 years (range 12.7–16.7 years), with four left and five right-sided osteotomies. The mean body weight was 84 kg (range 55–109 kg) and the average body mass index was 29 (range 19.4–36.8). Seven of the nine patients were beyond the 95th percentile of expected weight based on their height.

All patients had undergone in-situ pinning for a severe [11], stable [17] SCFE with a single cannulated screw at an average of 20 months (range 6–34 months) before the osteotomy. Two patients had bilateral SCFE, but only the

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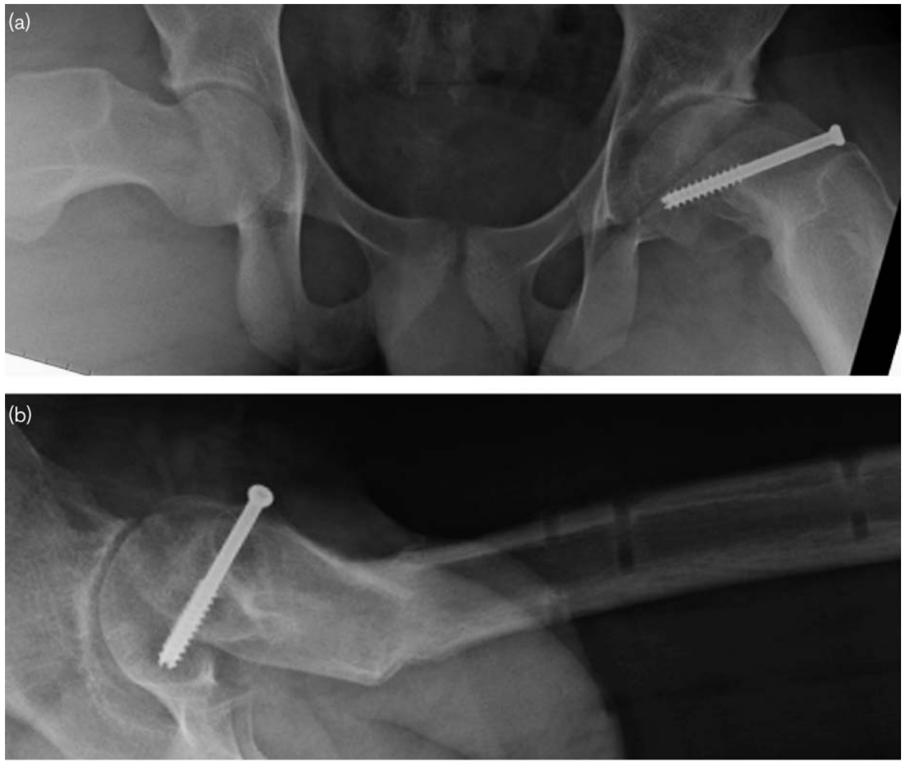
Fig. 3



(a) Preoperative and (b) postoperative lateral radiographs showing the flexion component of the osteotomy soon after fixator removal.

more severe side was treated with an osteotomy. The affected proximal femoral physis was closed at the time of osteotomy in each patient.

The mean duration of follow-up was 23 months (range 6–49 months). Clinical and radiographic data were available for all patients. The average operative time following induction of general anesthesia (including positioning and obtaining intraoperative radiographs) was 143 min (range 118–210 min). Intraoperative blood loss averaged 61 ml (range 50–100 ml), and no patient developed hemodynamic instability or required blood transfusion. The hospital stay averaged 2.4 days (range 2–4 days). Although superficial pin drainage requiring a 10-day course of oral antibiotics was common, no patient required hospital readmission, intravenous antibiotics or premature pin removal. The average time in the external fixator was 129 days (range 98–161 days). The fixator was removed under general anesthesia as a same day procedure and a hinged single leg hip–knee–ankle–foot orthosis was applied. The orthosis was discontinued approximately 3 weeks later. Although some restriction of knee motion was commonly seen while the patient was wearing the external fixator, full knee mobility was achieved within 6 weeks of fixator removal in all patients, without the need for formal physical therapy.

The preoperative and follow-up hip range of motion and radiographic results are shown in Tables 2 and 3. At latest follow-up, there was a 33° (range 7–90°) increase in hip flexion, 24° (range 5–38°) increase in internal rotation, 30° (range 7–55°) decrease in external rotation and 12° (range 0–20°) increase in abduction. Radiographic analysis revealed an average improvement of 22° (range 2–40°) in the anteroposterior head shaft angle and 57° (range 36–88°) in the lateral head shaft angle. No measurable loss of correction in any of the angular measurements was noted between immediate postoperative and latest follow-up radiographs. Following the osteotomy, there was a significant improvement ($P < 0.05$) in each of the five parameters of the Southwick score (Table 4 and Fig. 4). When the aggregate Southwick score was calculated using all five categories, the rating was poor in five and fair in four patients before surgery and good in all nine at follow-up.

The mean leg-length discrepancy measured on scanogram remained unchanged at 1.8 cm (Table 3). Although none of the patients underwent contralateral epiphysiodesis for correction of leg-length discrepancy, one patient required

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Table 2 Preoperative and postoperative range of motion of the affected hips

	Preoperative	Postoperative	*P* value
Flexion (°)	74 ± 25 (20–90)	106 ± 12 (95–130)	0.02
Internal rotation (°)	−5 ± 15 (−33–15)	17 ± 13 (5–40)	0.007
External rotation (°)	71 ± 20 (25–90)	41 ± 19 (5–68)	0.0003
Abduction (°)	29 ± 12 (14–50)	36 ± 6 (25–45)	0.23

The results are presented as the mean and standard deviation, with the range in parentheses.

Table 3 Preoperative and postoperative radiographic results of the affected hips

	Preoperative	Postoperative	*P*value
Anteroposterior head shaft angle (°)	112 ± 18 (84–138)	134 ± 15 (117–154)	0.004
Lateral head shaft angle (°)	72 ± 17 (57–101)	15 ± 10 (−2–26)	<0.0001
Leg-length difference (cm)	1.8 ± 0.9 (0.6–2.9)	1.8 ± 1.7 (0–4)	0.80

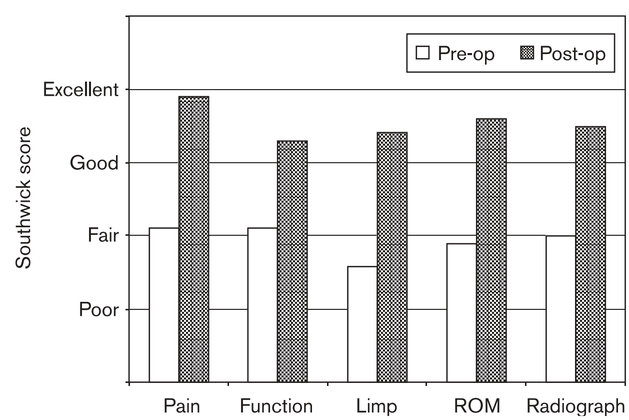
The results are presented as the mean and standard deviation, with the range in parentheses.

Table 4 Detailed preoperative and follow-up Southwick scores for all patients

	Pain		Function		Limp		Hip range of motion		Radiograph	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Case 1	Fair	Excellent	Fair	Good	Fair	Good	Poor	Good	Fair	Excellent
Case 2	Fair	Excellent	Fair	Good	Fair	Excellent	Good	Excellent	Fair	Good
Case 3	Fair	Excellent	Poor	Good	Poor	Excellent	Good	Excellent	Fair	Excellent
Case 4	Fair	Good	Fair	Good	Fair	Good	Fair	Excellent	Fair	Excellent
Case 5	Fair	Excellent	Good	Excellent	Fair	Excellent	Fair	Excellent	Fair	Good
Case 6	Good	Excellent	Good	Excellent	Poor	Good	Poor	Good	Fair	Good
Case 7	Fair	Excellent	Fair	Good	Poor	Good	Fair	Excellent	Fair	Excellent
Case 8	Fair	Excellent	Fair	Excellent	Poor	Excellent	Poor	Good	Fair	Excellent
Case 9	Fair	Excellent	Fair	Good	Fair	Good	Fair	Good	Fair	Good

a contralateral femoral shortening. No cases of wound infection, loss of reduction, postremoval fracture or avascular necrosis were noted. All osteotomies healed without further intervention. One patient developed transient chondrolysis with loss of hip mobility that improved over a 6-month period with a satisfactory radiographic outcome.

Fig. 4



Summary of the Southwick score of the affected hip preoperatively and at latest follow-up.

Discussion

There is general agreement that children who have a severe, chronic, stable SCFE should be treated with in-situ pinning, but there is considerable controversy regarding the indication, timing and technique for correcting secondary deformities in such a patient [4,6]. While correction at the site of the original deformity, that is the proximal femoral physis, makes intuitive sense, such an approach carries a significant risk of ischemic necrosis of the femoral head [4,5]. Southwick, in his classic report [11], described a subtrochanteric closing wedge biplanar osteotomy correction for moderate and severe degrees of SCFE. The original description [11] required the use of half pins inserted through the incision used for the osteotomy, with significant postoperative immobility secondary to bed rest and spica cast for approximately 2 months. Although recent modifications of the technique describe use of internal fixation [7–10,18], there are potential drawbacks such as deep infection related to extensive surgical exposures, delayed union and hardware failure. Rao *et al.* [8] reported (on Southwick osteotomy using plate fixation) an average blood loss of 950 ml, an operative time of 170 min and a hospital stay of 22 days. Similarly, Salvati *et al.* [9] reported an average blood loss of 817 ml, an operative time of 182 min and a hospital stay of 32 days. Compared with these two landmark studies [8,9], our current series of similar patients who underwent a percutaneous osteotomy had very acceptable clinical and radiographic

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results with a significant decrease in average blood loss (61 ml), hospital stay (2 days) and operative time (143 min) with no loss of correction or fixation.

Other authors have described the use of an external fixator for addressing proximal femoral deformities [13,19,20]. Colyer *et al.* [19] reported on two patients with SCFE who underwent open biplanar Southwick osteotomies [11] and stabilization with multiple anterior and lateral external fixation pins inserted through the osteotomy incision. Postoperative traction was used for 1 week with prolonged hospital stay. Ito *et al.* [20] performed a proximal femoral osteotomy in children with Perthes and SCFE deformities with a wide exposure and stabilization using monolateral external fixation. Although the results were comparable to reports using internal fixation, a significant number of patients required readmission for intravenous antibiotics, possibly related to some of the half pins being inserted through the operative incision. More recently, a percutaneous femoral osteotomy has been described for correcting deformities in children with developmental coxa vara [13] with operative time, blood loss and hospital stay comparable to that of the current report. The average time in the fixator, however, was over a month less in the younger and lighter children with developmental coxa vara than in the obese adolescents with SCFE. In another report of metadiaphyseal femur fractures in adolescents treated with a low profile Ilizarov fixator [16], an average of 138 days in the fixator was reported, which is similar to that in the current series.

Of the several potential benefits of the percutaneous femoral osteotomy, one advantage in typically large patients is the ability to achieve an accurate and sustained correction while avoiding extensive surgical exposure with associated blood loss and risk of deep infection. Another benefit is avoidance of problems related to internal fixation such as implant failure, risk of violating the proximal femoral growth plate, need to remove the previously placed cannulated screw and retained hardware requiring a second major surgical procedure for removing internal fixation. Being an opening wedge osteotomy, significant limb shortening that can occur with closing wedge correction is minimized, although not completely obviated. As supplemental spica cast application is not required with the current approach, early mobilization with a shorter hospital stay is possible.

Potential drawbacks with the percutaneous technique include the need to be familiar with use of the Ilizarov fixator, although other external fixator systems may be equally effective. The long duration and inconvenience of wearing the external fixator as well as pin site drainage are other drawbacks. By using proper-sized hydroxyapatite-coated half pins, proper technique of pin insertion [15], avoiding thermal necrosis while drilling, early use of oral antibiotics for pin site drainage and appropriate pin site releases and care, we have noted very few pin-related complaints. With appropriate preoperative counseling, these adolescents and their caretakers seemed to adapt well to the external fixator. Other shortcomings of this osteotomy are the possibility of increasing the complexity of future reconstructive procedures such as total joint arthroplasty owing to creation of secondary deformities and potential increased risk of infection following arthroplasty. Clearly, longer follow-up of a larger number of patients treated with such techniques at different centers is required before these issues can be fully resolved.

Nevertheless, on the basis of our preliminary results, this percutaneous technique appears safe and effective in correcting multiplanar proximal femoral deformities associated with SCFE in the adolescent population. It has potential advantages over commonly used open techniques and provides a viable alternative for fixation of proximal femoral osteotomies in typically obese patients with severe SCFE.

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