Open Reduction and Smooth Kirschner Wire Fixation for Unstable Slipped Capital Femoral Epiphysis

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Background: Reduction of unstable slipped capital epiphysis has a bad reputation, especially in severe slips. Treatment frequently causes avascular necrosis (AVN). This study analyzes the role of capsulotomy with evacuation of intraarticular fluid and gentle reduction done as an emergency procedure followed by fixation with unthreaded Kirschner wires (K-wires).

Methods: We treated 64 consecutive cases of unstable slips (37 boys and 27 girls) following the same protocol. Instability was recognized in those children who had experienced a fall or a stumble, followed by acute hip pain, with radiological evidence of capital femoral separation and ultrasonographic evidence of joint effusion. The protocol consisted of capsulotomy, evacuation of intraarticular effusion or hematoma, controlled gentle reduction, and fixation of the reduced physis by smooth K-wires. Surgery was done as an emergency procedure if possible within 24 hours after the onset of acute symptoms.

Results: There were 20 mild slips with slip angles less than 31 degrees, 24 moderate with slip angles between 31 and 50 degrees, 20 slips were severe with slip angles between 51 and 90 degrees. In 61 cases, reduction was successful without being followed by AVN. Three patients, 2 girls and 1 boy, developed partial AVN (4.7%). Two avascular necroses occurred in moderate slips, one in a severe slip, and none in the mild slips. The outcome of 60 patients (34 boys and 26 girls) with unstable slips could be evaluated clinically and radiographically with a mean follow-up of 4.9 years (range, 18 months–104 months). The Iowa hip score in these 60 cases reached an average of 94.5 points out of 100.

Conclusions: Open reduction and evacuation of intraarticular hemarthrosis or effusion detected by ultrasound and smooth K-wire fixation done as an emergency is a safe and reliable treatment option for unstable slips with a low AVN rate. The severity of the slip does not influence the rate of AVN and the outcome measured by the Iowa hip score.

Level of Evidence: Therapeutic, level IV.

Key Words: unstable slips, ultrasound, open reduction, smooth pinning, AVN rate

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Loder et al[1] coined the term *unstable* for *acute* slips, to keep them separate from *stable*, formerly called *chronic* slips.[2] By definition, a slip was unstable if because of discomfort, the patient could not bear weight and ambulate, even with the use of crutches.

The treatment of acute or unstable slips is highly controversial. Waldenström[3] suggested that chondral necrosis of the joint cartilage followed by avascular necrosis (AVN) of the femoral head can occur secondary to treatment of an acute slip. In contrast, Loder[4] feels that before any treatment, acute femoral head instability is the primary cause of a vascular insufficiency and resulting AVN of the epiphysis. Several centers advocated simple traction,[5] fixation in situ without reduction, or traction followed by open bone peg epiphyseodesis expecting a lower risk for AVN.[6–11] Uglow and Clarke,[12] after fixation in situ, saw better results in mild than in moderate or severe unstable slips.

The AVN rate after closed reduction of acute slips varies between 25% and 100%.[13–15] The timing of the reduction seems to be important. Peterson et al[16] and Phillips et al[17] reported an AVN rate lower in those treated within 24 hours or 48 hours. The AVN rate dropped to 7% when the reduction was done within 24 hours from presentation, whereas it was 20% in those children reduced with a delay of more than 24 hours.[18] Gordon et al[19] reported satisfactory results after early open reduction and cannulated screw fixation. Ten of 16 hips were treated within 24 hours; none developed AVN, whereas 2 of the 6 hips treated with delayed stabilization went on to AVN (33%). In contrast, Aronsson and Loder[20] reported on 2 groups of patients with unstable slips. The incidence of AVN was 88% in those treated within 48 hours in comparison to an incidence of only 32% in a second group treated after 48 hours after the use of traction.

Bonjour[21] has probably been one of the first to advocate an open reduction for acute slips. He reported a 10% incidence of AVN. Gekeler[22] used a threaded Kirschner wire (K-wire) for traction to help effect a gentle open reduction and reported no AVN in a series of 9 patients with acute slips.

In 1975, we began using open reduction followed by smooth pin stabilization of acute unstable slips as an emergency procedure. With the introduction of ultrasound to detect hip joint effusions in 1985, we have an additional tool to differentiate unstable from stable slips.[23] Since that year, *all patients* with suspected epiphyseolysis of the proximal femur have had ultrasound examination of their hips in addition to the radiographs. Ultrasound detects the slip and shows intraarticular hemarthrosis. The presence of a sanguine or clear effusion inside the joint of a slipped capital femoral

TABLE 1. History of Complaints, Acute Event, Side, Weight Bearing, Slip Angle, Ultrasound, Hours Passed After Acute Event, Residual Slip Angle After Reduction, AVN and Other Complications, and IOWA Hip Score at Follow-up

Patient No. (y)	Sex	Age, y + mo	Body Mass Index	History of Complaints	Acute Event	Side	Weight Bearing	Slip Angle Degress,Frog Lat	Ultrasound Omit: Blood	Acute Event, h	Residual Slip Angle Degrees, Frog Lat	AVN Complications	Iowa Hip Score
01 (1983)	Female	10 + 9	21.5	5 wk	Fall	Right	No	34	No	12	34 to 12	no	95
02 (1983)	Male	12 + 5	20.1	2 wk	Fall	Left	no	66	No	8	66 to 10	Wire malpositioning	94
03 (1983)	Male	12 + 4	21.5	2 wk	Fall	Left	No	52	No	6	52 to 22	No	90
04 (1984)	Male	14 + 5	25.8	1 wk	Fall	Left	No	75	No	12	75 to 28	No	98
05 (1985)	Female	13 + 9	22.5	3 mo	Fall	Right	No	55	Yes	>24 h	55 to 13	No	90
06 (1987)	Male	14 + 4	27.8	1 y	Fall	Right	No	60	Yes	12	60 to 20	No	No data
07 (1987)	Male	15 + 3	21.5	8 wk	Stumble	Left	No	32	Yes	>24 h	32 to 8	No	89
08 (1987)	Female	10 + 11	29.5	1 y	Fall	Right	No	59	Yes	6	59 to 8	No	96
09 (1988)	Male	15 + 1	28.7	2 wk	Fall	Left	No	48	Yes	8	48 to 22	No	93
10 (1988)	Male	11 + 5	22.5	4 wk	Fall	Right	Yes	20	Yes	>24 h	20 to 8	No	89
11 (1989)	Male	13 + 6	20.9	4 wk	Fall	Left	No	65	Yes	6	65 to 20	No	95
12 (1989)	Male	13 + 10	19.8	9 mo	Fall	Left	No	76	Yes	4	76 to 16	No	97
13 (1989)	Male	12 + 10	20.8	No history	Fall	Left	No	48	Yes	6	48 to 4	No	91
14 (1989)	Male	13 + 10	27.8	2 wk	Fall	Right	No	65	Yes	10	65 to 18	No	95
15 (1990)	Male	14 + 8	21.5	No history	Fall	Right	No	45	Yes	9	45 to 5	No	93
16 (1990)	Female	11 + 1	29.5	5 wk	Stumble	Right	No	32	Yes	>24 h	32 to 10	No	92
17 (1990)	Male	15 + 4	28.5	8 wk	Fall	Right	No	30	Yes	>24 h	30 to 8	No	No data
18 (1990)	Male	12 + 4	29.5	3 wk	No info	Right	Yes	20	Yes	15	20 to 10	Autistic child	95
19 (1991)	Male	12 + 3	31.5	2 wk	Fall	Left	No	80	Yes	6	80 to 13	Neurapraxia	96
20 (1991)	Male	14 + 1	22.5	3 mo	Fall	Left	No	30	Yes	>24 h	30 to 5	No	96
21 (1991)	Male	12 + 6	20.5	4 wk	Stumble	Left	No	28	Yes	>24 h	28 to 12	No	90
22 (1991)	Male	9 + 3	32.1	1 wk	Fall	Left	No	32	6 mm	15	32 to 10	No	93
23 (1991	Male	16 + 8	26.5	12 mo	Fall	Left	No	63	8 mm	8	63 to 15	No	90
24 (1991)	Male	14 + 4	27.4	8 wk	Fall	Right	No	50	5 mm	10	50 to 12	No	87
25 (1991)	Male	15 + 7	26.5	2 wk	Fall	Right	No	56	6 mm	9	56 to 18	No	94
26 (1991)	Female	14 + 1	26.5	8 wk	Fall	Left	No	45	7 mm	12	45 to 6	No	98
27 (1993)	Female	11 + 0	22.4	4 d	Fall	Right	No	27	8 mm	>48 h	27 to 14	Wire malpositioning	94
28 (1993)	Female	12 + 5	23.1	3 wk	Fall	Left	No	32	6 mm	10	32 to 14	AVN	82
29 (1994)	Female	11 + 8	17.3	2 wk	Fall	Right	No	65	8 mm	12	65 to 12	No	99
30 (1994)	Female	13 + 8	14.7	1 wk	Fall	Left	No	52	10 mm	8	52 to 15	No	94
31 (1994)	Male	14 + 5	22.1	4 wk	Fall	Left	No	30	6 mm	12	30 to 10	Wire malpositioning	98
32 (1994)	Male	11 + 4	19.4	2 wk	Stumble	Left	No	27	Yes	20	27 to 8	Short wires	99
33 (1995)	Female	10 + 6	33.4	1 wk	Stumble	Right	No	37	6 mm	15	37 to 5	No	99
34 (1995)	Female	11 + 2	26.5	4 wk	Stumble	Left	Yes	15	Yes	>48 h	15 to 0	No	98
35 (1995)	Female	10 + 1	31.4	4 wk	Stumble	Left	No	37	Yes	32	37 to 5	No	99
36 (1995)	Female	12 + 1	15.1	6 wk	Fall	Left	No	52	6 mm	12	52 to 20	No	90
37 (1995)	Female	12 + 4	21.1	2 wk	Stumble	Left	No	38	11 mm	10	38 to 8	No	94
38 (1995)	Female	14 + 4	18.4	1 wk	Fall	Left	No	90	10 mm	>62 h	90 to 22	No	90
39 (1995)	Male	13 + 0	22.4	3 wk	Fall	Left	No	40	6 mm	15	40 to 11	No	98
40 (1996)	Female	11 + 3	20.9	3 wk	Fall	Left	Yes	20	5 mm	>24 h	20 to 8	No	99
41 (1996)	Female	10 + 4	24.2	No history	Fall	Right	No	60	8 mm	>24 h	60 to 10	AVN	90
42 (1996)	Female	9 + 10	22.1	10 wk	Stumble	Left	No	34	6 mm	15	34 to 10	No	99

43 (1996)	Female	11 + 6	23.2	3 wk	Fall	Right	No	28	Yes	8	28 to 8	No	98
44 (1996)	Male	13 + 4	20.8	2 d	Fall	Left	No	72	10 mm	6	72 to 18	No	99
45 (1996)	Female	10 + 7	24.5	3 wk	Fall	Left	No	45	7 mm	8	45 to 10	No	99
46 (1997)	Female	12 + 8	25.0	9 mo	Fall	Left	No	40	Yes	10	40 to 10	No	99
47 (1997)	Female	11 + 10	24.5	No history	Fall	Left	No	65	5 mm	8	65 to 10	No	88
48 (1997)	Male	13 + 7	25.3	4 wk	Fall	Left	No	25	Yes	22	25 to 4	No	97
49 (1997)	Male	11 + 3	19.3	6 mo	Fall	Left	No	28	Yes	15	28 to 10	No	99
50 (1997)	Male	12 + 11	22.6	4 wk	Fall	Left	No	45	7 mm	10	45 to 12	No	98
51 (1997)	Male	13 + 2	23.1	3 mo	Fall	Right	No	23	Yes	>24 h	23 to 15	No	98
52 (1997)	Male	13 + 1	24.1	No history	Fall	Left	No	35	9 mm	15	35 to 5	No	99
53 (1998)	Female	11 + 1	27.5	3 mo	Stumble	Right	Yes	18	Yes	18	18 to 5	No	97
54 (1998)	Male	12 + 8	22.5	6 wk	Fall	Left	Yes	20	5 mm	15	20 to 5	No	No data
55 (1998)	Female	10 + 3	24.4	2 mo	Stumble	Right	Yes	10	5 mm	>24 h	10 to 0	No	No data
56 (1999)	Male	13 + 8	27.5	2 mo	Fall	Left	No	50	8 mm	>24 h	50 to 10	AVN	80
57 (1999)	Female	11 + 9	25.5	3 mo	Stumble	Left	Yes	10	6 mm	10	10 to 0	No	96
58 (2000)	Male	11 + 7	23.5	4 mo	Fall	Right	No	50	8 mm	10	50 to 10	No	94
59 (2000)	Male	11 + 1	27.5	2 mo	Stumble	Left	Yes	10	5 mm	8	10 to 0	No	92
60 (2000)	Female	8 + 5	26.5	4 wk	Fall	Left	No	35	6 mm	>24 h	35 to 10	Short wires	95
61 (2000)	Male	14 + 10	21.7	1 wk	Fall	Left	No	55	10 mm	10	55 to 10	No	98
62 (2000)	Male	15 + 6	22.5	3 mo	Fall	Left	No	50	6 mm	8	50 to 10	No	93
63 (2000)	Female	11 + 1	23.5	2 wk	Fall	Right	No	32	8 mm	20	32 to 8	No	96
64 (2001)	Male	14 + 2	21.6	1 wk	Fall	Left	No	65	10 mm	8	65 to 10	No	98

epiphysis (SCFE) indicates that there is an element of instability caused by the acute event and a good chance that, with a gentle maneuver, the slip can be reduced before pinning. In the absence of an effusion, instability caused by a slip cannot be expected.

METHODS

During a 19-year period, we treated a cohort of 20 hips with mild slips (<30 degrees), 24 hips with moderate slips (31–50 degrees), and 20 hips with severe slips (51–90 degrees). Institutional review board approval for this work was consented by the institution. Our study presents the AVN rate of this cohort of 64 unstable SCFE treated with the same protocol. The midterm results of 60 patients seen at a follow-up clinic are presented. The 4 patients missing in the follow-up group had been seen for at least 12 months postoperatively and had shown neither chondrolysis nor AVN (Table 1).

Given the onset of acute hip pain after a fall or a stumble, radiographic appearance of a slip, and the ultrasound documentation of a joint effusion, we have proceeded with emergency treatment of all as previously defined unstable slips. Forty-nine (76.6%) of the 64 patients were seen and operated on within 24 hours after the onset symptoms, 15 patients (23.4%) were admitted with a delay of more then 24 hours because they had initially been in a primary care hospital before being transferred to our tertiary center. No delay of surgery was accepted as soon as the patient had been admitted with an unstable slip. By protocol, emergency surgical treatment has included ventral capsulotomy, to evacuate the effusion or hematoma, and gentle open reduction. In our retrospective analysis, pure blood was noted in 53 patients (82.8%), whereas in 11 (17.2%), a blood-stained rose or clear effusion was evacuated.

Eight surgeons were involved in the surgical procedure, the first author being responsible in 35 of the 64 cases. The operative approach consists of the following surgical protocol (Figs. 1A–D). Without previous attempt at closed reduction, a Watson Jones approach is used to expose the proximal femur and hip joint. An anterior arthrotomy is performed with a longitudinal capsulotomy. The joint effusion is evacuated; transparent joint fluid was observed in 20 patients, and blood or blood clots were noted in 44 patients. A central K-wire is introduced by a power drill from the greater trochanter into the femoral neck, stopping short of the metaphyseal border of the slip, as monitored with the image intensifier. The power drill is removed. With the surgeon's fingertip inside the casule, the gap between metaphysis and epiphysis can be palpated. A gentle reduction maneuver is done by the assistant joggling the leg into flexion, abduction, and internal rotation, monitored by the finger inside the joint. The gentleness of the maneuver is absolutely important. The surgeon's finger inside the capsule helps to avoid an undesired abrupt movement. As soon as the surgeon notices the successful reduction of the metaphysis on the epiphysis, the assistant advances the previously introduced K-wire with the reinstalled power drill into the femoral head, stopping short of the articular cartilage, and providing temporary fixation of the epiphysis on the metaphysis.

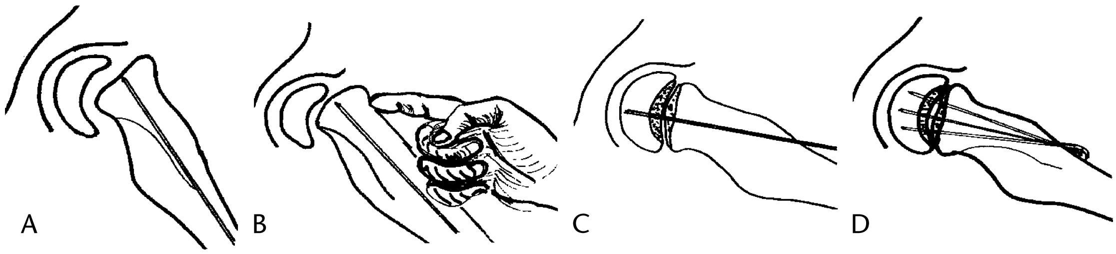

FIGURE 1. Surgical protocol. A, Unstable slip: K-wire is introduced, stopping short of metaphyseal border. B, Joggling maneuver with surgeon's fingertip controlling gentle reduction. C, After achieved reduction, the K-wire is advanced to fix the head. D, Two additional K-wires are introduced to guarantee stability of reduced slip.

The extremity is lowered on the table to control the position of the K-wire in relation to the physis and the joint space. With the lower extremity gently rolled into the frog position, the amount of reduction and the position of the K-wire is verified with the image intensifier. No force is applied to correct a preexisting stable slip; only the unstable part of the slip is reduced. The stable part of so-called *acute on chronic* slips measures between 4 and 30 degrees and does not cause problems for the first K-wire to be placed. If the position of the reduced physis is satisfactory, 2 or 3 additional K-wires are introduced to achieve a stable fixation of the reduced capital epiphysis. The protruding ends of the K-wires are cut off approximately 1 to 2 cm from the lateral femoral cortex. The ends of the wires are bent to greater than 90 degrees and impacted into the cortex to avoid either migrating further into the epiphysis or backing out and irritating the fascia lata (case 48, Figs. 2–5; case 64, Figs. 6–10).

There were several problems encountered in the K-wire insertion that must be attributed to the learning curve of this procedure. In 7 cases, inadvertent intraarticular positioning of a K-wire occurred. Four times this was recognized during the initial procedure and immediately corrected. In the other 3 occurrences, it was recognized postoperatively, necessitating a return to the operating room for correction (cases 2, 27, and 31). None of these 7 children developed chondrolysis or AVN.

FIGURE 2. Case 48: male, aged 13 years 7 months, hip complaints for 3 weeks, fall in school yard, unable to bear weight, operated on 20 hours after accident. Frog lateral radiograph of left hip shows unstable slip of 25 degrees.

RESULTS

After the protocol treatment of their unstable slips, all 64 patients in this series were followed for at least 12 months. Three children (4.7%) out of 64 treated for unstable SCFE developed AVN. In all 3 hips, chondrolysis was initially noted, followed by a segmental AVN of the weight-bearing part of the femoral head. The AVN was recognized within 6 months after the surgical reduction and stabilization (cases 28, 41, and 56). In 2 patients (cases 28 and 41), the AVN was treated by intertrochanteric corrective osteotomy, placing viable cartilage in the weight-bearing zone 18 months after their slip. Patient 28 had an additional cheilectomy.

The surgeons followed the strict instruction not to use undue force during the surgical reduction. Incomplete reduction was accepted with the option that a corrective osteotomy could be done at a later stage, if necessary. The average slip angle for these patients measured before open reduction

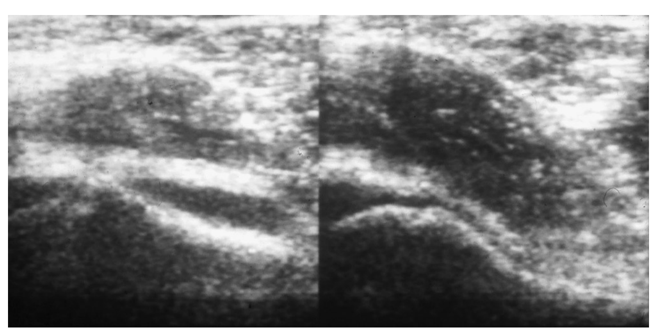

FIGURE 3. Ultrasonography of patient in Figure 2 detects effusion and slip of left hip (right side of image). The right side (left half of image) shows neither slip nor effusion.

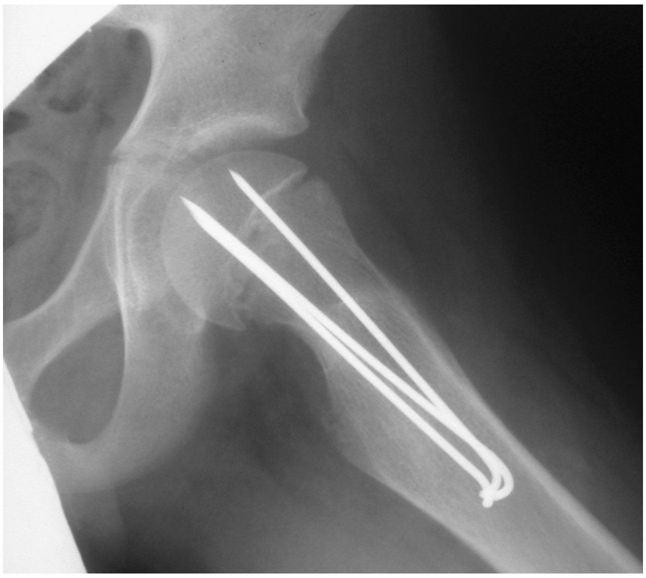

FIGURE 4. Frog lateral radiograph of patient in Figure 2 after open reduction and pinning, residual slip of 4 degrees.

was 42.6 degrees. After open reduction, an average change of 32.0 degrees was achieved, and the average slip angle was reduced to 10.6 degrees (Table 1). The residual angle is dependent on the stable part of the slip. In this series, only once did we observe residual slip deformity that may have been an indication for a secondary corrective osteotomy (case 38). This was refused by the patient because she did not experience clinical symptoms from her residual radiographic deformity.

Long-term follow-up was available in 60 of 64 of our patients who had been treated as previously described for an unstable slip, 47 patients were personally examined by the first author, 13 patients were contacted by questionnaire. The 4 patients who were not available for long-term control had

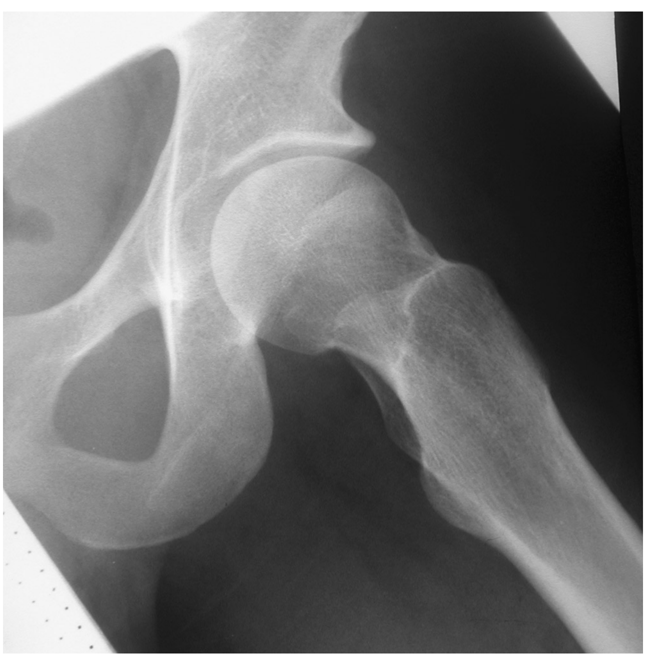

FIGURE 5. Frog lateral of patient in Figure 2 at follow-up at 22 years (Iowa score, 97 points).

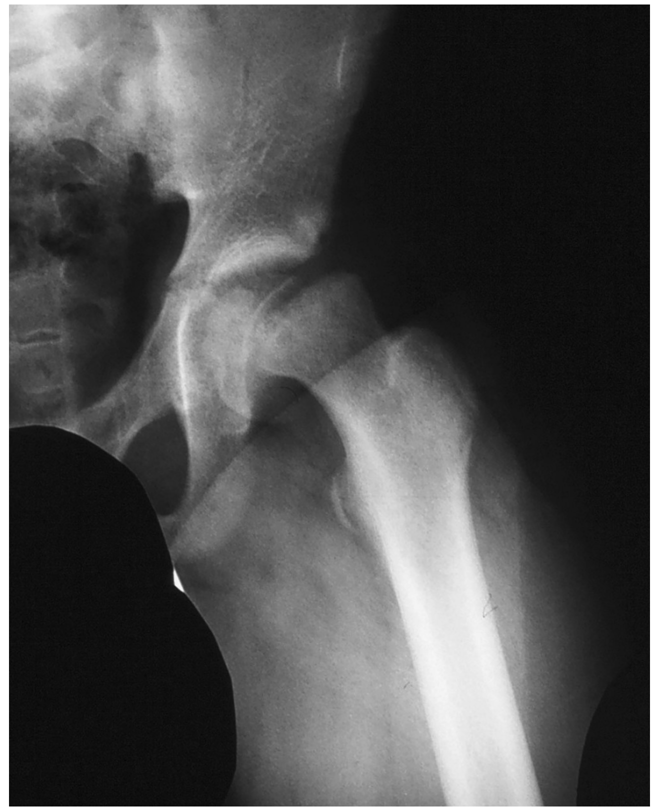

FIGURE 6. Case 64: male, aged 14 years 2 months, 1 week history of hip pain, fall from bike, operated on 8 hours after accident. Radiograph of left hip shows unstable slip of 65 degrees.

FIGURE 7. Anteroposterior radiograph of patient in Figure 6 after open reduction and pinning.

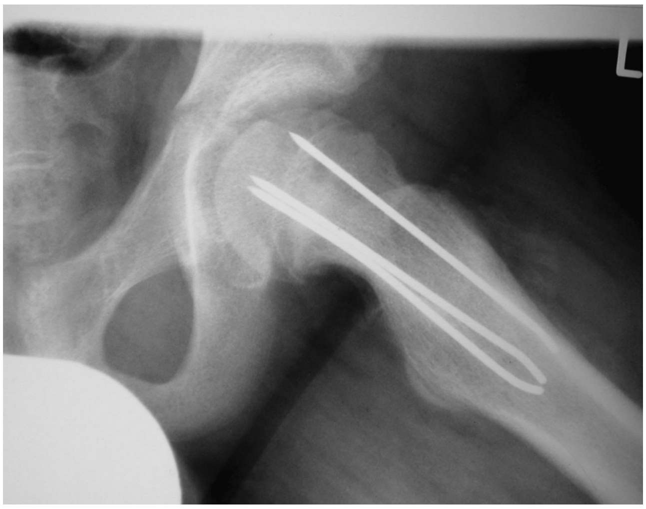

FIGURE 8. Frog lateral radiograph of patient in Figure 6 after open reduction and pinning, residual slip of 10 degrees.

been seen for at least 12 months after their slip to exclude any chondrolysis or AVN. A follow-up radiograph was obtained at an average of 4.9 years after surgery (range, 18–120 months). The outcome for the 60 patients who were examined and/or contacted for the long-term follow-up was measured by the Iowa hip score.[24] This mostly assesses clinical features, and to a lesser extent radiological changes, and is accepted in the evaluation of results after SCFE in adolescents and adults.[6,7] The Iowa hip score (top score, 100 points) was 94.5 points in 60 patients, with the 3 with AVN (cases 28, 41, and 56) included.

FIGURE 9. Anteroposterior radiograph of left hip of patient in Figure 6 at follow-up at age 16 years 5 months.

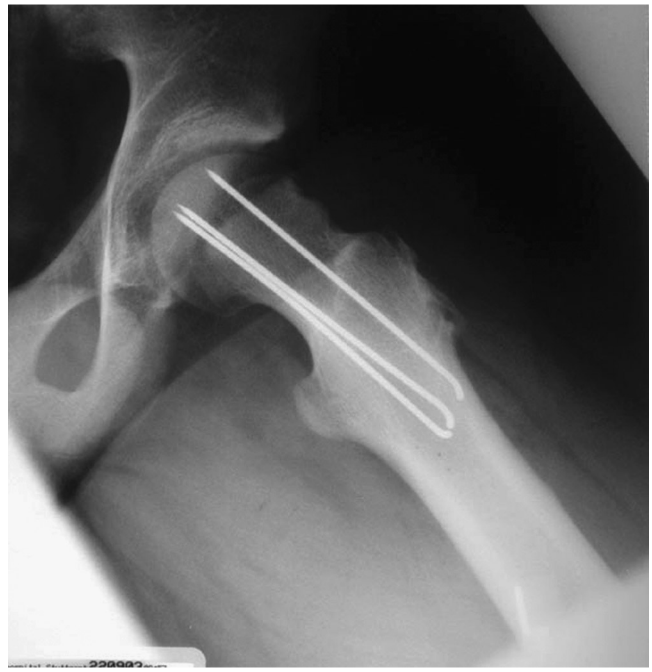

FIGURE 10. Frog lateral radiograph of left hip of patient in Figure 6 at follow-up at age 16 years 5 months.

DISCUSSION

Starting in 1983 and up until the present, we have used the same surgical protocol in the treatment of variably unstable slips. Much of the satisfactory clinical outcome for our patients is attributed to both a low rate of AVN (4.7%) and our observed seemingly relative lack of need of a secondary procedure for residual deformity, with an average Iowa hip score of 94.5 points in 60 patients.

A rather low figure of AVN in our unstable slips may be attributable to one of the following clinical interventions: (1) prevention of a time delay by doing surgery as an emergency, having to accept the fact that referral to our tertiary center can be delayed; (2) evacuation of the intraarticular hematoma or effusion by capsulotomy; and (3) gentleness of the reduction controlled by the fingertip of the surgeon.

The timing of the reduction seems to be important. By protocol over the years, we have attempted to treat our unstable slips as an emergency. Upon arrival, patients with a suspected slip are immediately evaluated by clinical examination, radiographic imaging, and ultrasound imaging. Working in a tertiary center, only 76.6% were operated on within 24 hours after the onset of symptoms. A total of 23.4% came with a delay of more than 24 hours, having been initially seen in a primary hospital. Two of our patients who developed AVN had come with a delay of more than 24 hours after the acute event, whereas one was treated within the 24-hour zone. At least in case 28, the necrosis was not caused by delayed treatment.

The unfavorable results of closed reduction in acute slips without evacuation of the intraarticular fluid are well known.[1,13,15] Open reduction allows for evacuation of the effusion and hematoma, which in turn seems to minimize the occurrence of AVN.

In the past, we have occasionally measured the effusion by millimeters by ultrasound but have not quantified the fluid evacuated during arthrotomy. As such, we were unable to establish a correlation between the severity of deformity (slip angle) and the amount of intraarticular pressure. We had observed pure blood in 82.8% of arthrotomies, whereas 17.2% had a blood-stained rose or clear effusion. In 2 of the cases who developed AVN, there was blood (cases 41 and 56); case 28 had a blood-stained effusion. Our figures suggest but do not prove the importance of the evacuation of the joint fluid or hematoma, as we had not measured the intraarticular pressure before the capsulotomy. However, Herrera-Soto et al[25] have recently demonstrated that a marked increase in intraarticular pressure occurs after acute closed reduction of a severely displaced unstable SCFE. In this clinical setting, Herrera-Soto et al[25] were also able to demonstrate that the acute and dramatic increase in intraarticular pressure readings returned to more normal values after the effect of an arthrotomy.

We feel that our method of obtaining a reduction is very gentle; with the capsule opened, the reduction is carefully done by the assistant and controlled by the surgeon's finger. The assistant must not get the surgeon's finger painfully caught inside the capsule by a rough reduction maneuver. We feel that it is gentle as any other method such as 1 or 2 weeks of continuous traction. The low AVN rate achieved compares favorably with those of other series of unstable slips treated by traction with an AVN rate of 6%,[26] 10%,[27] and 17%.[28]

The rate of AVN in our series did not depend on the severity of the slip. Only one AVN was observed in a girl with a 60-degree severe slip. Two of the necroses occurred within the group of 24 moderate slips with slip angles of 32 degrees and 50 degrees, respectively. As expected, there was no AVN encountered in the 20 mild slips. This is different from other series, where the severity of the unstable slips is responsible for the risk of AVN.[8] If we excluded the 9 patients with mild unstable slips (of our definition) with joint effusion seen on ultrasound who could still bear weight, the AVN rate of the other 55 patients is 5.4%.

We must discuss our definition of instability in SCFE because it is, in part, different from the definition established by Loder et al.[1] We feel that although some children with acute slips are still able to walk with pain and the help of crutches, these slips were physiologically better classified as unstable. We categorize these slips as unstable because of the presence of the intraarticular effusion in addition to the acute event of a fall or a stumble followed by acute hip pain and the radiographic presence of a slip. In this clinical setting, we anticipate a relative reducibility without an inordinate risk of subsequent AVN. In contrast to this, if there is no effusion detected by ultrasound, the slip is most certainly stable and cannot (and should not) be moved by a reduction maneuver. Supported by our clinical and ultrasonography experience, we introduce a modified definition of physeal stability. In our hands, in addition to the clinical appearance of sudden pain, ultrasonography gives the key information about physeal stability. We could confirm that a sanguine or clear effusion, as identified by ultrasonography, occurred only in hips with unstable (mobile) physis. This includes 9 out of 20 mild slips, *unstable* by our definition, which would be classified as stable by Loder, as they had acute pain after trauma with the ability to bear weight impaired but not lost.

Effecting reduction of the slip deformity serves to minimize secondary impingement from the metaphyseal bump. We are convinced that our procedure is considerably less invasive than a surgical dislocation and shows equally favorable results.[29,30] We also acknowledge that several of our mild SCFE cases would have remodeled spontaneously, as observed by some authors.[31,32] Smooth unthreaded K-wires allow stabilization without enforcing local growth arrest. We saw continued growth of the femoral neck after the reduction in mild slips, but we did not observe a secondary slip during further growth. Two children had to have an exchange of the K-wires 1 and 2 years after the initial operation because the K-wires had become too short (cases 32 and 60). In three other cases, a warning to have a close control of symptoms was sufficient until final closure of the growth plate.

The Iowa hip score of 60 patients controlled in a follow-up clinic is listed in Table 1. An average score of 94.5 points was counted. To our knowledge, this is the largest series of unstable slips published using an identical protocol. The low AVN rate of 4.7% has had an influence on the further outcome, measured by the Iowa hip score. In our follow-up of 60 patients with unstable slips, the 3 patients with partial AVN are included (case 28: score, 82; case 41: score, 90; case 56: score 80). The score in 2 AVN patients was taken after a redirectional intertrochanteric osteotomy in cases 28 and 41 and a cheilectomy in case 28.

On an annual basis, we continue to treat about the same total number of patients with SCFE. The yearly number of stable and unstable slips has continued on with the same frequency. We have continued to date using the same protocol of emergency open reduction for patients presenting with acute hip pain and imaging evidence of an unstable SCFE. A minor change has been the fixation of mild reduced unstable slips, where currently, an 8-mm core diameter cannulated screw is used instead of K-wires. The moderate and severe slips are fixed by smooth K-wires according to the established protocol.

CONCLUSIONS

In children who have experienced a stumble or a fall followed by severe hip pain and the ability to bear weight lost or decreased, ultrasound detection of an effusion helps to establish the indication for surgery. Our treatment protocol consists of open reduction with evacuation of hemarthrosis or effusion performed as an emergency, followed by smooth K-wire fixation of the reduced slip. Using the same protocol in 64 consecutive patients with unstable slips, an AVN rate of 4.7% was observed. The severity of the slip did not influence the AVN rate. The Iowa hip score showed an average of 94.5 points out of 100 points in 60 patients reached at a follow-up.

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