Slipped capital femoral epiphysis (SCFE) is a disorder in which there is acute or progressive displacement of the capital femoral epiphysis from the femoral neck through the physeal plate. The femoral neck is displaced mainly in the anterior direction, resulting in varus deformity of the proximal femur. The goals of treatment for SCFE are to stabilize the epiphysis and prohibit further displacement so as to prevent the development of chondrolysis or avascular necrosis of the femoral head. Artificially causing accelerated closure of the upper femoral physis is a secondary goal of most treating physicians. The attempt to obtain physeal closure to prevent further slippage of the epiphysis is still controversial. Ogden and Southwick recommended an extra articular bone graft in addition to fixation pins to hasten physeal closure. Because premature closure of the capital femoral epiphysis can lead to growth disturbance of the proximal femur, Segal suggested the use of a smooth pin to prevent premature closure of the growth plate in children with significant growth potential.

**Background:** Treatment of a slipped capital femoral epiphysis (SCFE) should stabilize the epiphysis and prevent complications. Attempting to obtain physeal closure is still controversial. The purpose of this study was to evaluate the clinical results and complications after treatment of SCFE.

**Methods:** From 1989 to 2000, 12 patients (14 hips) underwent pinning for treatment of SCFE. For acute and acute-on-chronic slippage, longitudinal traction was attempted for reduction. Patients with chronic slippage received fixation in situ. All patients were available for follow-up for an average of 63 months.

**Results:** Nine of the 14 hips had excellent or good functional results, and 5 had fair results. One hip developed avascular necrosis of the femoral head with a fair result. There was no chondrolysis or osteoarthritis of the joint at the most recent follow-up. Physeal closure in 9 hips occurred at an average of 16 months. The change in articulotrochanteric distance averaged 5.4 mm.

**Conclusion:** Although most functional results were not adversely influenced after premature closure of the physeal plate of consideration should be given to the device, such as a dynamic screw, that stabilizes the epiphysis and prevents premature physeal closure in patients who have significant growth potential. To understand the influence of growth disturbance of the proximal femur and the effect of dynamic screw fixation, long-term follow-up is mandatory.


**Key words:** slipped capital femoral epiphysis (SCFE), physeal plate closure.
Treatment modalities for SCFE include application of a hip spica, open bone peg epiphysodesis, osteotomy, fixation with multiple pins or screws, and fixation with a single screw to prevent further slippage of the epiphysis. The purpose of this study was to evaluate the clinical results of surgical treatment of SCFE as well as complications and premature closure of the physis.

MATERIALS

A retrospective study involving 14 hips in 12 patients with SCFE treated using internal fixation was conducted. There were 11 boys and 1 girl. The average age at the time of surgery was 11 years and 11 months (range, 8 years 10 months to 15 years). There were 6 right hips, 4 left hips, and 2 with bilateral involvement.

The initial evaluation included a complete history of trauma, medical disease, and infection, and the time since the onset of symptoms. No patient reported any endocrine or other systemic illness. The duration of symptoms was defined as the time period from clinical presentation to surgical treatment after diagnosis of SCFE. Physical examination included gait, pain, and limited range of motion of the hip joint. A complete blood count, erythrocyte sedimentation rate, and radiographic anteroposterior (A-P) and frog leg views of the pelvis were obtained. The Klein line from the anteroposterior radiograph of the pelvis was positive in all patients.

The degree of displacement was measured on the frog leg radiograph of the pelvis according to the method described by Southwick. The degree of slip was graded as mild, moderate, or severe according to the following criteria: mild slip was one in which the degree of displacement was less than 30°; moderate slip was 30° to 50°; and severe slip was more than 50°. The slip was defined as acute if there was a sudden onset of symptoms of less than 3 weeks’ duration. The acute-on-chronic type of SCFE occurred when a patient with an extended history of symptoms of chronic SCFE was affected with an acute increase in pain and loss of motion of the affected hip. Symptoms longer than 3 weeks were defined as chronic SCFE.

Physial plate stability at the time of presentation was classified by Loder et al. A slip was classified as unstable if the patient suffered from severe pain that made walking impossible, even with crutches. A slip was classified as stable if walking and weight-bearing were still possible with or without crutches.

Internal fixation was used in all hips. The method of treatment varied with the duration of symptoms. Acute or acute-on-chronic slippage was treated with gentle manipulation, longitudinal traction, and closed reduction under fluoroscopic imaging, followed by internal fixation with pins or screws. Violent reduction or repeated manipulation was avoided. Chronic slippage was treated with in situ fixation without an attempt at reduction.

Four groups were classified based on the numbers of pins or screws used. In the early part of the series, multiple threaded Knowles pins were used. Later, one cannulated screw was used to engage the center of the capital femoral epiphysis to avoid complications. Multiple Knowles pin fixation was used in 4 cases, single Knowles pin fixation in 2 cases, multiple screws in 1 case, and a single screw in 7 cases. Postoperatively, partial weight-bearing with crutches was allowed on the operated legs for 6 weeks. Patients were followed-up regularly after discharge.

Radiographs of the pelvis were taken immediately after the operation, at 6 weeks, 12 weeks, and then at 3-month intervals until the physisal plate closed. The epiphysis position, degenerative changes of the hip joint, chondrolysis, avascular necrosis of the femoral head, trochanteric overgrowth, and any growth disturbance of the head and neck were evaluated. The articulotrochanteric distance as defined by Edgren was measured. Physeal fusion was defined when 50% or more of the physis had linear closure.

The final results were graded according to the Heyman and Herndon classification system. The result was rated excellent if the patient had a normal range of motion of the hip, no limp, and no pain; good if the patient had no limp or pain, and only slight limitation of internal rotation; fair if the patient had slight limitation of abduction and internal rotation but no pain or limp; and poor if the patient had a mild limp, slight pain after strenuous exercise, and slight limitation of hip motion in abduction, internal rotation, and flexion. All patients were available for follow-up for an average of 63 (range, 14 to 131) months.
RESULTS

The results of the study are summarized in Table 1. Pain and limping were the most common symptoms preoperatively. All patients complained of pain, and 8 patients had a limp. Ten patients had a vague trauma history. Pain usually developed with a falling accident or during exercise. There were 2 acute slips, 10 chronic slips, and 2 acute-on-chronic slips. Based on the degree of displacement, there were 4 mild slips, 6 moderate slips, and 4 severe slips. According to physeal plate stability at the time of presentation as classified by Loder, there were 11 stable slips and 3 unstable slips.

At the latest follow-up, 9 of the 14 hips had excellent or good functional results, and 5 had fair results. Both hips in acute slip had fair results. Chronic slips had excellent results in 4, good results in 3, and fair results in 3 cases. Both acute-on-chronic slips had excellent results. Excellent or good results followed treatment in 3 of the 4 mild slips, 4 of the 6 moderate slips, and 2 of the 4 severe slips. Seven stable slips had excellent or good results, and 4 had fair results. Patients with unstable slips had excellent results in 2 and a fair result in 1 case.

The internal devices were removed from 4 hips when there was radiographic evidence of physeal closure. One Knowles pin broke at the time of follow-up, and it was impossible to remove during the operation. However, there were no symptoms at the latest follow-up 8 years postoperatively, and the final result was excellent (Fig. 1). None of the patients

### Table 1. Summary of Demographic Data and Results

<table>
<thead>
<tr>
<th>Case</th>
<th>Gender</th>
<th>Age (yr+mo)</th>
<th>Side</th>
<th>Type of slip</th>
<th>Fixation method</th>
<th>Duration of follow-up (months)</th>
<th>Time to fusion (months)</th>
<th>Clinical result</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>13+8</td>
<td>R</td>
<td>Chronic</td>
<td>3 cancellous screws</td>
<td>24</td>
<td>6</td>
<td>Excellent</td>
<td>Coxa breva</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>12+3</td>
<td>L</td>
<td>Chronic</td>
<td>1 Knowles pins</td>
<td>131</td>
<td>14</td>
<td>Good</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>15+0</td>
<td>R</td>
<td>Acute-chronic</td>
<td>2 Knowles pins</td>
<td>95</td>
<td>16</td>
<td>Excellent</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>14+5</td>
<td>R</td>
<td>Chronic</td>
<td>2 Knowles pins</td>
<td>87</td>
<td>4</td>
<td>Good</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>10+9</td>
<td>R</td>
<td>Acute</td>
<td>3 Knowles pins</td>
<td>87</td>
<td>8</td>
<td>U</td>
<td>AVNFH</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>12+1</td>
<td>L</td>
<td>Acute</td>
<td>1 Cancellous screw</td>
<td>74</td>
<td>8</td>
<td>Fair</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>12+5</td>
<td>L</td>
<td>Chronic</td>
<td>1 Cancellous screw</td>
<td>73</td>
<td>42</td>
<td>Good</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>13+0</td>
<td>R</td>
<td>Chronic</td>
<td>1 Cancellous screw</td>
<td>66</td>
<td>4</td>
<td>Good</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>10+1</td>
<td>R</td>
<td>Chronic</td>
<td>1 Cannulated screw</td>
<td>66</td>
<td>23</td>
<td>Excellent</td>
<td>-</td>
</tr>
<tr>
<td>9A</td>
<td>F</td>
<td>10+1</td>
<td>L</td>
<td>Chronic</td>
<td>1 Cannulated screw</td>
<td>66</td>
<td>23</td>
<td>Excellent</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>12+4</td>
<td>R</td>
<td>Acute</td>
<td>3 Cannulated screws</td>
<td>51</td>
<td>U</td>
<td>Excellent</td>
<td>Coxa breva, Coxa vara</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>12+4</td>
<td>L</td>
<td>Chronic</td>
<td>1 Cannulated screw</td>
<td>20</td>
<td>N</td>
<td>Excellent</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>8+10</td>
<td>L</td>
<td>Chronic</td>
<td>1 Cannulated screw</td>
<td>29</td>
<td>N</td>
<td>Fair</td>
<td>-</td>
</tr>
<tr>
<td>12A</td>
<td>M</td>
<td>10+0</td>
<td>R</td>
<td>Chronic</td>
<td>1 Cannulated screw</td>
<td>14</td>
<td>N</td>
<td>Fair</td>
<td>-</td>
</tr>
</tbody>
</table>

**Abbreviations:** M: male; F: female; yr: year; mo: months; R: right; L: left; U: Unknown; N: no.
received prophylactic fixation for the contralateral asymptomatic hip. One patient (case 12) developed a mild slip of the contralateral side 2 years after the first operation, which was fixed with 1 cannulated screw. The result was fair at the latest follow-up.

Neither postoperative infection nor myositis ossificans around the head of the screw was noted. There was no chondrolysis or osteoarthritis of the hip joint at the time of follow-up. One hip developed avascular necrosis of the femoral head (Fig. 2). The patient had acute, severe SCFE that was treated with closed reduction and internal fixation with 3 Knowles pins. Avascular necrosis of the femoral head was noted 6 months postoperatively. The final result in this patient was fair at 74 months of follow-up.

Physeal closure occurred in 9 hips at an average of 16 (range, 4 to 42) months. The change in the articulotrochanteric distance averaged 5.4 (range, 0 to 15) mm. Eight hips developed coxa breva, and 6 hips developed coxa vara. After the physis had closed, postoperative radiographs demonstrated little change in the head-shaft angle.

Fig. 1 Case 3. (A) Preoperative radiograph showing a 15-year-old boy with severe slipped capital femoral epiphysis. (B) The slip was fixed with 2 Knowles pins. (C) The Knowles pins were removed after the physis was closed. One pin broke, and removal of the proximal portion was impossible.
DISCUSSION

The annual incidence of SCFE has been reported to be 2 per 100,000 in the general population. Minomiya et al. reported an incidence of 0.2 per 100,000 in Japan. The estimated incidence of SCFE in Taiwan is not available. The age at presentation in boys is between 10 and 16 years, and for girls between 10 and 14 years of age. When a patient with SCFE presents at an age outside of these ranges, underlying endocrine or systemic disorders should be considered. All patients except 1 in our series were older than 10 years of age. However, no patient had any endocrine disorder or other systemic illness. A male predilection for SCFE has been reported to be 2.4 to 1 with the left hip being affected twice as often. In our series, only 1 girl was noted, and the right hip was involved more often than the left hip (8 versus 6 hips).

Complications after treatment of SCFE included avascular necrosis of the femoral head (AVNFH), chondrolysis, implant loosening, subtrochanteric and femoral neck fracture, pin penetration, implant breakage or extrusion, and infection. Internal fixation with pins or screws has been the standard treatment for acute or chronic SCFE for many years. However, the risk of penetration associated with the use of multiple pins or screws is higher than that with single screw fixation. In recent years, most authors have suggested single screw fixation to provide adequate fixation and decrease the complication rate.

An increased incidence of AVNFH has been reported with acute and unstable slips. Iatrogenic injury to the epiphyseal vessels can occur during manipulation and stabilization of the femoral head if the fixation device violates the posterior cortex of the femoral neck, and hardware placement intrudes into the vulnerable superior quadrant of the femoral head. The incidence of AVNFH is related to the type of slip, technique of pin placement, and number of pins or screws. One of our cases developed AVNFH 6 months after the operation. The possible reasons for AVNFH in that case included acute and severe slips, an attempt at manipulation for reduction, and internal fixation with 3 Knowles pins.

Chondrolysis was first described by Elmslie in 1913. The etiology of chondrolysis associated
with SCFE remains unknown. The condition was previously believed to be a result of synovial malnutrition, ischemic injury to the articular cartilage, or excessive cartilage pressure. Modern theory suggests an immunologic and autoimmune disorder within the hip joint. The treatment modalities associated with the occurrence of chondrolysis include manipulative reduction, prolonged immobilization, and realignment osteotomy of the proximal femur. Manipulation for closed reduction and pin penetration of the femoral head has been shown to be associated with the development of chondrolysis. Of the 4 patients in our series who received gentle manipulation for reduction, none developed chondrolysis.

Although accelerated physeal plate closure in SCFE treated with in-situ fixation has been demonstrated, the exact mechanism of premature closure is unknown. Reports suggest that in situ pin or screw fixation may be associated with accelerated closure of the physeal plate. With single screw fixation, Ward reported physeal plate closure at an average of 13 (range, 2-34) months postoperatively in 29 of 49 hips, and showed no correlation to age at the time of fixation, race, or gender. Stanton reported physeal closure at an average of 12 (range, 0-22) months postpinning. Goodman reported physeal closure at an average of 9.6 (range, 6-30) months after single screw fixation. Nine hips in our study showed premature closure of the physeal plate at an average of 16 (range, 4-42) months after the operation.

In a prospective study of dynamic screw fixation for patients with SCFE, Kumm reported that the average time to physeal closure was almost the same in both genders, ranging from 1.2 to 6.3 years. In none of the 29 hips was any growth disturbance, including greater trochanteric overgrowth, coxa breva, or coxa vara, seen. The authors concluded that the technique of dynamic screw fixation provides sufficient immediate and long-term fixation, does not promote premature physeal closure, and permits normal hip development.

Premature closure of the proximal femoral physis can lead to relative greater trochanteric overgrowth, coxa vara, and coxa breva. Functional disability may occur following growth disturbance of the proximal femur. Coxa vara and coxa breva can result in a decrease of the abductor lever arm and decreased pelvic-femoral stability. Changes in the biomechanics of the hip joint result in a limping gait with easy fatigue and pain from increased energy expenditure. In a retrospective study of 33 hips that used pinning of a juvenile SCFE, Segal et al. reported growth disturbances of the proximal femur in 64% of the hips. They suggested using a smooth pin to prevent premature closure of the growth plate in children with significant growth potential. Hansson devised a hook-pin to prevent premature closure of the physis, while allowing for normal longitudinal growth of the femoral neck.

In our study, we found that growth disturbance of the proximal femur was not correlated to clinical results. Six cases with unilateral involvement had a leg length discrepancy of more than 1 cm at the latest follow-up. This result supports the point made by Segal that the gradual closure of the growth plate after pinning in SCFE apparently allows the abductor mechanism to compensate for its increasing mechanical disadvantage, and limits the functional disability that occurs.

Prophylactic pinning of the contralateral hip for patients with SCFE is controversial. None of the hips in this study received prophylactic pinning for the contralateral hip because none of the patients had an endocrine disorder or systemic illness. However, 1 patient (case 12) developed a second symptomatic slip 2 years later prior to skeletal maturity. After 29 months of follow-up, the physis was still open, but the result was fair.

We conclude that 9 cases in this study had an excellent or good functional result in spite of the fact that 8 cases developed coxa breva and 6 cases developed coxa vara deformity after the physis had closed. Although most of the functional results were not adversely influenced after premature closure of the physeal plate of the capital femoral epiphysis, consideration should be given to an internal fixation device such as a dynamic screw that stabilizes the epiphysis and prevents premature physeal closure in patients who have significant growth potential. However, screw breakage may occur if the physeal plate does not fuse early. For understanding the growth disturbance of the proximal femur and the
effect of dynamic screw fixation, long-term follow-up is mandatory.

REFERENCES

股骨頭骨骺滑脫症治療後之生長板早期癒合

陳金恩 郭繼陽 王清貞

背 景： 股骨頭骨骺滑脫症的治療是固定股骨頭骨骺，避免其進一步的滑脫以避免合併症的發生，但嘗試使生長板癒合則仍有所爭議。這篇文章研究的目的是評估我們對此種疾病治療的臨床結果，以及評估其治療後的合併症。

方 法： 從1989年至2000年，12位病人共14個髖關節接受手術治療。其中有2個急性滑脫，10個慢性滑脫及2個急性在慢性滑脫(acute-on-chronic)。對於急性及急性在慢性滑脫，嘗試以閉鎖復位再以鋼釘固定；慢性滑脫則原位固定。手術後定期追蹤，平均追蹤時間為63個月。

結 果： 在臨床的評估中，9個髖關節有良好的結果，5個髖關節有尚可的結果。一個股骨頭發生缺血性壞死，但沒有病人發生軟骨溶解或骨關節炎。其中9個髖關節有生長板早期癒合的情形，平均癒合時間為16個月。而關節週圍距離的改變平均為5.4公釐。

結 論： 雖然生長板早期癒合並沒有影響到臨床的結果，但為了避免生長板早期癒合或許可採用動力性鋼釘固定。至於生長板早期癒合造成的髖關節變形會造成什麼影響，則仍需更長期的追蹤。

(長庚醫誌 2002:25:811-8)

關鍵字：股骨頭骨骺滑脫症(SCFE)，生長板癒合。