Original article

Severe slipped capital femoral epiphysis: A French multicenter study of 186 cases performed by the SoFOP

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Abstract

Introduction: The treatment of severe slipped capital femoral epiphysis (SCFE) remains controversial. Despite numerous treatments being available, the outcome of published studies has been variable. Recent studies emphasize that poor reduction of the severe SCFE is responsible for the appearance of joint cartilage lesions and progression towards early osteoarthritis. But surgical reduction of severe SCFE also results in a significant rate of necrosis.

Objective: Evaluate the results of various treatment strategies for severe SCFE and identify the optimal course of action.

Material and methods: This was a French multicenter retrospective study of severe SCFE cases (>45° displacement) evaluated a minimum of 12 months after treatment. The stability of the slipped epiphysis, type of the treatment, delay before treatment, early and short-term complications, Harris and WOMAC functional scores and radiological signs of femoroacetabular impingement (FAI) at the last review were evaluated. A total of 186 cases of severe SCFE in 182 patients were included. One hundred and seven (58.7%) of these were male. The average age was 13 years. The average follow-up was 23 months. The average displacement was 60°. The SCFE was considered stable in 94 cases (50.5%) and unstable in 92 cases (49.5%). The main surgical treatments used by the various centers were in situ fixation (ISF), lateral Dunn, anterior Dunn and reduction using traction or under anesthesia (for unstable forms).

Results: In the stable SCFE cases, there were 6 cases of necrosis (6.4%), all of which occurred after reduction by osteotomy; there were 32 cases of radiological FAI (34%), 30 of which occurred after ISF. The necrosis rate in the unstable SCFE cases was 21.7%; one (11%) after ISF, seven (19%) after anterior Dunn, eight (21%) after preoperative reduction and three (43%) after lateral Dunn.

Conclusions: The results of this study confirm the diverse nature of SCFE treatments available and the variability of their results. When selecting a treatment for severe SCFE, the goal is to stop the slip and also to prevent osteoarthritis by correcting the hip deformities. The “anterior” Dunn procedure was able to achieve these two goals, while having a lower complication rate than the other reduction techniques.

Level of evidence: IV.

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1. Introduction

Slipped capital femoral epiphysis (SCFE) corresponds to slipping of the epiphysis relative to the neck through the growth plate. This is the most common hip condition in adolescents, with an estimated incidence of 1 per 10,000 children in the West [1–3].

Although in situ fixation (ISF) is the generally accepted treatment for minor SCFE, the treatment of more severe SCFE cases remains controversial [1]. Although remodeling is possible, cases of severe SCFE that are fixed in situ often quickly progress towards labrum lesions and osteoarthritis, which occurs even more quickly when large residual deformities exist [4–6]. The objectives of this study were to report on the various treatment methods used within the SoFOP (French Society of Pediatric Orthopedics) and then to

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analyze the complications associated with these methods to define a decision tree for the optimal course of action.

2. Materials and methods

This was a French multicenter retrospective study of severe SCFE cases with more than 45° displacement [Southwick method [7]] treated between January 2010 and June 2013. Secondary SCFE cases and patients who had previously been operated in the proximal femur were excluded. The minimum follow-up was 1 year; this made it possible to determine the occurrence of complications and, in particular, detect occurrences of delayed osteonecrosis.

All the patient records were evaluated at the participating centers by one of the three co-authors. The demographics, nature of the treatment, and time between admission and treatment were recorded. The SCFE cases were labelled as stable or unstable based on Loder’s criteria [8]; the complication rates were compared between these two subgroups and to those reported in published studies. When MRI was performed, the preoperative epiphyseal perfusion in unstable forms of SCFE was recorded. All the initial radiographs, immediate postoperative radiographs and those at the last follow-up were then analyzed by the three authors together. The radiographs from the last follow-up visit were reviewed for signs of femoroacetabular impingement (FAI) [9–11]. The functional outcomes were evaluated using the Harris Hip Score [12] and the WOMAC score [13].

Comparisons between the different surgical techniques and the differences between the pre- and postoperative radiological parameters were made using paired r-tests; a P-value below 0.05 was considered significant. The statistical analysis was carried out using Excel (Microsoft, Redmond, WA, USA).

2.1. Patient demographics

Twenty-five health care facilities (with 22 of them being university hospitals) participated in the study and contributed 186 cases of severe SCFE (182 patients). One hundred seven (58.7%) of them were male; the sex ratio was 1.36. The average age at the time of the diagnosis was 13 years (range: 8.5–17) (Fig. 1).

The average weight was 61 kg (range: 25–110) and the average body mass index was 24.8 (range: 15–37). In 138 patients (76%), the SCFE was unilateral and considered severe; the right leg was affected in 63 patients and the left in 75 patients. The SCFE was bilateral in 44 patients (24%); 4 of them had severe SCFE in both legs and the 40 others had severe epiphyseal displacement in only one leg (right in 16 cases, left in 24).

The average displacement was 60° (range: 45–100°). Based on Loder’s classification, 94 cases (50.5%) were stable and 92 (49.5%) were unstable. The average follow-up was 23 months (range 12–42).

2.2. Treatment methods

Various treatment methods had been used (Table 1):

- in situ fixation with screws or K-wires [14];
- preoperative reduction using progressive traction and/or under general anesthesia followed by fixation [14];
- surgical reduction:
  - according to Dunn’s original technique [15,16], which we labelled “lateral” Dunn,
  - with hip dislocation according to the technique described by Leunig, Slango and Ganz [17,18], which we labelled “modified” Dunn,
  - with femoral neck osteotomy below the growth plate,
  - with trans-growth plate osteotomy and femoral neck shortening through an anterior approach according to the modified Compère technique [14,19,20], which we labelled “anterior” Dunn.

2.3. Stable SCFE

There were 94 cases of stable severe SCFE. The average displacement was 57° (range: 45–90°). The treatments carried out on these cases are shown in Table 1. The average procedure time was 2 hours 44 min (± 60 min) for osteotomy procedures and 1 hour 13 min (± 60 min) for in situ fixation. Weight bearing was allowed

![Fig. 1. Age distribution for the 182 patients with severe slipped capital femoral epiphysis, the average age was 13 years.](image-url)
an average of 76 days (range: 30–120) after an osteotomy procedure and 30 days (range: 1–90) after in situ fixation.

2.4. Unstable SCFE

There were 92 cases of unstable severe SCFE. The average displacement was 61° (range: 45–100°). Preoperative epiphyseal perfusion had been evaluated by MRI in all 92 cases (50%). The epiphysis was normally perfused in 76 cases (82.6%) and not perfused in 16 cases (17.4%). The treatments carried out are listed in Table 1. Five hips (5.5%) had been operated on within 6 hours of admission, 10 (11%) between 6 and 24 hours, and 77 (84%) after 24 hours.

3. Results

3.1. Stable SCFE

The average angle of cases treated by all types of osteotomy procedures went from 60° before the surgery (range: 45–90°) to 9° after (range: 0–35°). The displacement at the last follow-up of cases treated by ISF was 58° (range: 45–85°). Early surgical revision was performed in seven cases (7.4%) because of inappropriate screw length or insufficient fixation resulting in secondary displacement. The recovery period was marked by chondrolysis in three cases (3.2%); one had been treated by anterior Dunn, one by ISF and one by preoperative reduction.

The overall rate of necrosis at the last follow-up was 6.4%. The necrosis rate as a function of treatment type is listed in Table 2. Radiological signs of FAI at the last follow-up were found in 32 cases (34%), 30 of these after ISF and 2 after partial preoperative reduction. Functional scores were available in 53 of the stable cases (56%). The WOMAC score was significantly better in the osteotomy group than the ISF group (Table 3).

3.2. Unstable SCFE

The initial displacement (all treatments together) was reduced 70.4% (average initial angle: 61°, average postoperative angle: 18°). The rate of early complications was 5.4%; there were two cases of secondary displacement, one of an overly long screw and two of insufficient fixation with secondary displacement. At the last follow-up, two hips (2.2%) had chondrolysis.

The necrosis rate as a function of treatment type is listed in Table 2. The amount of displacement reduction was not significantly different between cases of severe SCFE that developed necrosis and the overall series. All the cases of necrosis occurred in patients who had been operated more than 24 hours after admission. The necrosis rate was 75% in the cases where the epiphysis was not perfused in the preoperative evaluation and 15.7% in the cases where it was perfused normally. The necrosis rate as a function of the treatment type is listed in Table 4.

Twenty hips (21.7%) had radiological signs of FAI: 6 after ISF, 10 after preoperative reduction, 3 after lateral Dunn and 1 after anterior Dunn (insufficient reduction). Functional scores were available in 52 of the unstable cases (56%). The scores were better in the cases treated by osteotomy than in those treated with preoperative reduction, but this difference was not statistically significant (Table 5).

4. Discussion

The natural history of SCFE reveals a close relationship between residual deformity of the proximal femur and the occurrence of early osteoarthritis [3,5,6]. In situ fixation, which has long been considered the gold standard treatment, stops the slip and has a low complication rate. Recent published studies have defined the idea of FAI and specified its risk of osteoarthritis, leading to renewed interest in reduction techniques [1,3,9,17,18,21]. Unfortunately, many studies have a small sample size, heterogeneous classification systems and very controversial results [1–3,9,17,18,22–27].

Together, these observations bring the decision to treat severe SCFE with in situ fixation or with anatomical reduction into the forefront. This decision must not be made based only on the short-term complication rate, namely the occurrence of necrosis [1]. Mills emphasizes the falsely reassuring nature of ISF for severe SCFE, which is only rarely the final treatment and only serves to delay addressing the problem [1].

4.1. Stable severe SCFE

In the current study, ISF was used in 37 cases (39.5%), but reduction was carried out in 57 cases (60.5%). This can be explained in part by the influence of recently published studies and in part by some dissatisfaction about the long-term outcomes of ISF procedures among SoFOP members, which are fairly heavily represented in this study (71% of the university hospitals in France).

Reductions carried out through the anterior Dunn procedure led to better results than the other techniques. The necrosis rate

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Necrosis rate as a function of treatment used in cases of stable and unstable severe slipped capital femoral epiphysis (SCFE).</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>In situ fixation, n (%)</td>
</tr>
<tr>
<td>Stable severe SCFE</td>
<td>37 (0)</td>
</tr>
<tr>
<td>Unstable severe SCFE</td>
<td>9 (11)</td>
</tr>
</tbody>
</table>

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<tr>
<th>Table 3</th>
<th>Functional scores in the stable severe slipped capital femoral epiphysis (SCFE) cases at the last follow-up.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Osteotomy (n = 27)</td>
</tr>
<tr>
<td>WOMAC</td>
<td>3.8</td>
</tr>
<tr>
<td>Harris Hip Score</td>
<td>92.5</td>
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<tr>
<th>Table 4</th>
<th>Necrosis rate as a function of treatment used for cases of normally perfused, unstable severe slipped capital femoral epiphysis (SCFE).</th>
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</thead>
<tbody>
<tr>
<td>ISF, n</td>
<td>Anterior Dunn, n</td>
</tr>
<tr>
<td>0 (0%)</td>
<td>3 (11.1%)</td>
</tr>
</tbody>
</table>

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<tr>
<th>Table 5</th>
<th>Functional scores for cases of unstable severe slipped capital femoral epiphysis (SCFE) at the last follow-up.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Osteotomy (n = 25)</td>
</tr>
<tr>
<td>WOMAC</td>
<td>3.4</td>
</tr>
<tr>
<td>Harris Hip Score</td>
<td>91.2</td>
</tr>
</tbody>
</table>

WOMAC: The Western Ontario and McMaster Universities Osteoarthritis Index; ISF: in situ fixation; ns: not significant.
was 5.5% and about 85% reduction was achieved (initial angle 60°, postoperative angle 9°). These results are even more meaningful because they were achieved in a multicenter study involving different surgeons, while studies describing other reduction techniques reported different results among centers [2–4,9,17,18,22,23].

This procedure was described initially by Compère in 1949 [19] and then by Lagrange and Rigault in 1965 [20], but had been gradually abandoned because of its high necrosis rate. It was readopted in 1994 by certain French teams [14], but with significant changes: an osteotomy is performed through the growth plate and the femoral neck is shortened. The advantages of this method include reduction of the displacement through the anterior Huerter approach, far away from circumflex vessels, without the need for trochanterotomy or hip dislocation.

The modified Dunn procedure with hip dislocation has been the subject of multiple publications in the past years; the results have been variable and the necrosis rate in stable cases is between 0 and 10% [2,3,22,23]. Uncertainty regarding the long-term outcome of the joint cartilage after hip dislocation [4] and the large variability in the results as a function of the experience of the surgical teams [23] has limited the use of this procedure. In the current study, only one modified Dunn procedure was carried out and necrosis eventually occurred in this patient. The current study also confirms published data [14] on the high rate of necrosis after the lateral (original) Dunn procedure (25%), arguing in favor of abandoning this technique.

Radiological signs of FAI were found in 32 cases (34%) of stable severe SCFE that were treated by ISF, while none of the patients treated with the anterior Dunn procedure had this abnormal radiographic finding.

After a 2-year follow-up, the WOMAC score was statistically higher in the severe SCFE cases treated by the anterior Dunn technique than the ones treated by ISF. But the follow-up is not long enough to determine the relationship between early radiological signs of FAI and their functional repercussions.

4.2. Unstable severe SCFE

The treatments proposed in the literature are controversial, both in terms of the degree of urgency and the reduction technique [1,4,8,14,23–27]. Some cases of unstable severe SCFE can be complicated by vascular lesions, which occur at the moment of the slip and before any treatment is possible. In the current study, preoperative MRI exams revealed that 16 cases (17.4%) of unstable severe SCFE were under-perfused. This is an essential prognostic element and it seems indispensable for the patient to be fully informed. This is consistent with results of other studies [4,8,27,28].

The reduction indication and the time frame in which to perform it are still controversial because the published results are contradictory [1,4,8,14,22–27]. Published series have revealed variable results depending on the time elapsed between admission and treatment. Madan [2] and Sankar [22] found no effect of the time elapsed between the slip occurring and the surgical treatment. However, other authors [4,24–26,29,30] have stressed the importance of treatment, particularly reduction, being carried out within 24 hours of the slip occurring. They stress that the slipped epiphysis itself is responsible for the vascular compression and that the epiphyseal perfusion must be re-established urgently, but do not provide proof.

Since more than 95% of the patients in this study were operated more than 6 hours after admission, we cannot analyze the effect of delayed treatment on the occurrence of necrosis. The availability of a surgical team experienced in treating unstable severe SCFE and the importance of evaluating epiphyseal perfusion by MRI must be balanced against delaying the treatment.

The current study shows that ISF treatment for unstable cases (contrary to stable cases) has an 11% necrosis rate. Similarly, preoperative reduction with progressive traction and/or manipulations under general anesthesia is the cause of necrosis in 21.7% of cases, with 63% of the initial displacement being reduced. The anterior Dunn procedure was able to reduce the displacement by 76% with a 19.4% necrosis rate; if the cases of non-perfused SCFE are excluded, this necrosis rate is 11.1%. This latter percentage is directly related to the surgical technique. The results of the study show that the preferred procedure is the anterior Dunn procedure, given its ability to reduce the displacement and its necrosis rate, which is comparable and even lower than that reported in published studies where more complicated techniques were used [2,22,23].

Radiological signs of FAI were found in 20 cases (21.7%) of unstable severe SCFE; most of them (80%) occurred following ISF or preoperative reduction. Only 5% of these cases were attributed to the anterior Dunn procedure.

After 2 years of follow-up, the functional scores appeared better for cases of severe SCFE treated by osteotomy than those treated with preoperative reduction.

5. Conclusion

This study shows that the treatment for severe SCFE must be made with the goal of not only stopping the slip as quickly as possible, but also correcting structural deformities in the proximal femur. Anatomical reduction of slips of more than 45° seems to be necessary to avoid the appearance of FAI. Although the risk of necrosis cannot be ignored, it must not be the only element considered when selecting a treatment method for stable and unstable severe SCFE.

By using the anterior Dunn procedure, it is possible to achieve the reduction goal with a complication rate that is clearly lower than that of other reduction techniques, namely the modified Dunn procedure with hip dislocation that is currently in vogue. These findings are even more meaningful because they are based on a multicenter study.

This work allows us to outline a course of action that seems optimal in cases of stable and unstable severe SCFE: traction to relieve pain upon admission, MRI to analyze epiphyseal perfusion (for unstable cases) and anterior Dunn procedure as soon as an experienced surgical team is available.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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