Screw placement in slipped upper femoral epiphysis: is good the enemy of better?

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Abstract *Introduction and aims* A single hip screw is the recommended method of fixation for slipped upper femoral epiphysis (SUFE). Current practice favours the placement of the screw in the centre of the femoral head on both anteroposterior and lateral planes to avoid the risks of chondrolysis and avascular necrosis (AVN). We investigated the correlation between different positions of the screw in the femoral head and the prevalence of AVN, chondrolysis, late slippage and the time to epiphyseal closure.

Methods The clinical notes and radiographs of 38 consecutive patients (61 hips) who underwent single screw fixation for SUFE were evaluated retrospectively with a mean follow-up of 36 months. Two-way ANOVA and the post hoc test was performed to analyse the correlation between the different variables and the outcome at the 5% level of significance.

Results There were 16 acute slips, 18 chronic slips and ten acute-on-chronic slips. Seventeen slips were treated prophylactically. Mild slip was encountered in 39 hips, moderate slip in four and severe slip in one. The central–central position was only achieved in 51% of cases. The most significant results of the study were as follows: (1) no

significant difference between the time to epiphyseal closure and the position of the screw, and (2) no late slippage or chondrolysis was observed in our series.

Conclusion Our results showed that the positioning of the screw other than in the centre of the femoral head has the ability to provide physeal stability and has no correlation with the timing to closure of the epiphysis and the risk of avascular necrosis or chondrolysis. We therefore recommend that other positions be considered if the “optimal central–central position” is not initially achieved – specifically for the treatment of mild slip – as the potential hazards from several attempts to achieve the optimum position outweigh the benefits.

Keywords Hip pain · Physeal closure · Screw fixation · SUFE

Introduction

Slipped upper femoral epiphysis (SUFE) is one of the most common causes of hip pain in adolescence [1]. The upper femoral epiphysis is held in the acetabulum by the ligamentum teres, and the femoral metaphysis displaces on the femoral head, leading to the child presenting with a painful hip of gradual or acute onset. The majority of the displacement occurs through the zone of hypertrophy and may extend into the distal aspect of the zone of proliferation and into the proximal metaphysis [2, 3]. However, there is disagreement about whether the histological changes seen in the zone of hypertrophy occur before the SUFE, or are caused by the SUFE itself [2, 3]. The diagnosis may often be delayed due to mild symptoms or to its relative rarity. In many cases, the diagnosis is delayed because the patient complains of pain in the knee. The clinician does an

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extensive work up for knee pain and does not consider the possibility that the patient may be experiencing referred pain from the hip. It is important for clinicians in primary care and accident and emergency settings to remember that knee pain in an adolescent, particularly if the adolescent is overweight, may be coming from the hip [4]. Untreated, SUFE tends to progress, with increasing risk of deformity and osteoarthritis. Hence, early diagnosis and treatment is essential for optimal results.

Plain radiographs of the hip, including antero-posterior (AP) and frog(-lateral) or true lateral projections, usually confirm the diagnosis of SUFE. Several treatment methods have been described, such as single screw fixation [5–8], multiple screws [9, 10], pinning [11, 12], open epiphyseodesis [13, 14], osteotomies [15], manipulation [16, 17] and even non-operative treatment [18].

The goals of screw fixation for the treatment of SUFE are to achieve physeal stability, prevent further slippage, avoid avascular necrosis (AVN) and chondrolysis and promote physeal closure [4]. A single hip screw is the recommended method of fixation with current practice favouring the placement of the screw in the centre of the femoral head on both the AP and lateral planes (Fig. 1). The purpose of our study was to investigate the correlation between the different positions of the screw and the timing to physeal closure, and the prevalence of late slippage, avascular necrosis and chondrolysis.

Patients and methods

Between 1995 and 1999, 43 patients were treated surgically for the treatment of slipped upper femoral epiphysis. Five patients (six hips) were lost to follow-up (three patients' notes and X-rays were not available, and two patients had moved away following their index surgery). The medical records and radiographs were examined retrospectively for the remaining 38 patients (61 hips). Patients were grouped into acute (symptoms <3 weeks) chronic (symptoms $\geq$ 3 weeks)

and acute-on-chronic [1]. An absence of radiographic signs of remodelling or new bone formation at the epiphyseal-metaphyseal junction was also a prerequisite for the diagnosis of acute slips. The lateral head-shaft angle was measured on the frog-leg lateral radiographs of the hips (Fig. 2). This measurement was performed on the preoperative, postoperative and follow-up radiographs and served as a comparison for the severity of the slips and also as a measurement of the presence or absence of slip progression. The degree of slip was measured by calculating the head-shaft angle on lateral radiographs and was graded as mild (0–29), moderate (30–60) and severe (>60) [19]. All patients with SUFE were treated in a standard manner with a single percutaneous in-situ screw, with the exception of one severe slip where the slip was reduced prior to fixation with a single screw. All patients had their surgery within 24 h from the time of presentation to our institutions. All patients apart from the severe slip had their SUFE fixed using an orthopaedic table. Care was taken to avoid traction, flexion and internal rotation of the hip in an attempt to avoid incidental spontaneous reduction which might have increased the risk of avascular necrosis. The position of the screw was measured by the method developed by Mulholland and Gunn [20] and recently applied to SUFE screw position by Aronson and Carlson [6]. The screw was in position 1 when its central axis was over the centre line of the femoral head or within a distance equal to one-half the diameter of the screw. The screw was in position 2 when the distance between its axis and the centre line of the femoral head was between one-half and one screw-diameter, and the screw was in position 3 when its axis was more than one screw-diameter from the centre line of the femoral head. The position is given as two numbers: the first is for the position of the screw as seen on the AP radiograph and the second is for the position as seen on the lateral radiograph.

The criterion of Ingram et al. [21] was used for radiographic evidence of hip chondrolysis: a cartilage space measuring 3 mm or less. Avascular necrosis was

Fig. 1 **a** Central–central position on an antero-posterior (AP) radiograph. **b** Central–central position on a lateral (frog) radiograph

Fig. 2 Lateral (frog) radiograph demonstrating the measurement of the lateral head-shaft angles (X and Y). Measurement of the severity of the slip is created by the intersection of a line drawn along the femoral shaft and a line perpendicular to a line drawn along the epiphyseal edge

documented in the presence of sclerosis and collapse in the femoral head [22].

Serial follow-up radiographs were evaluated for physeal closure, and the time to fusion was documented. Physeal fusion was determined to have occurred when 50% or more of the physis had undergone linear closure [23]. Radiographs were also used to evaluate the presence or absence of degenerative changes in the hip joint according to the system of Boyer et al. [24].

All measurements were made by the principal authors and subsequently reviewed and agreed upon by the senior author to limit interobserver variation. A musculoskeletal radiologist cross-checked the observations for AVN and chondrolysis. Using the STATA computer programme (Stata statistical software, release 9.1; StataCorp, College Station, Tex.), we carried out two-way ANOVA and the post hoc test to analyse the correlation between the different variables and the outcome at the 5% significance level.

Results

The cohort comprised 14 girls and 24 boys. The mean age of the girls at the time of the surgery was 12.1 ± 1.4 years and that of the boys was 14.2 ± 1.2 years. The mean time from the onset of the symptoms to the time of presentation to our institutions was 3 days for acute slips (1–12 days) and 28 days for chronic slips (22–65 days). The length of follow-up was 39 months (range: 24–56 months). There were 16 acute slips, 18 chronic slips and ten acute-on-chronic slips. Seventeen hips were treated prophylactically. Mild slip was encountered in 39 hips, moderate slip in four and severe in one. The central–central position (position 1.1) was achieved in 31 hips only (51%) (Fig. 1; Table 1).

Table 1 Number of hips (percentage) in which the various screw positions were achieved

Screw position	Total (<i>n</i> = 61)
1.1	31 (50.8%)
1.2	6 (9.8%)
1.3	7 (11.5%)
3.1	8 (13.1%)
3.3	9 (14.8%)

The threads of the screws crossed the epiphyseal line in all cases. The fixation was achieved by Richard cannulated screw (6.5 mm) in 27 hips and AO cannulated screw (7.3 mm) in the remaining 34 hips.

Thirteen patients had the screw subsequently removed following physeal closure (two due to pain from the back-up of the screws and 11 had prophylactic removal). For the cases involving the back-up of screws, there was no clear reason for this occurrence as patients had their slip fixed in a standard manner with a single screw in the central–central position in the femoral head and had their physes closed within an appropriate time. Eight of the 11 screws were prophylactically removed at the patients' request as they were engaged in a competitive sport or were about to join the national service. Three patients had their screw prophylactically removed as they experienced constant pain over the greater trochanteric area which failed to respond to conservative measures. Following a football injury, one patient sustained an undisplaced, subtrochanteric fracture of the proximal femur at the level of the entry point of the screw into the lateral cortex shortly after the screw was removed. The fracture was treated successfully using a hip spica. No cases of postoperative complications were reported.

The most significant results of the study were: (1) the absence of a significant correlation between the time to epiphyseal closure and the position of the screw [$F_{(4,56)} = 1.40$, 95% confidence interval (CI): 9.802465–10.71366, $P = 0.2469$] (Table 2); (2) no late slippage was

Table 2 Relationship between screw position and time to physeal fusion

Screw position	Degree of slip (P ^a : mild:moderate:severe)	Type of the slip (P ^a : acute, chronic, acute-on-chronic)	Mean number of months to fusion
1.1	9:20:2:0	9, 7, 8, 7	10.3
1.2	1:5:0:0	1, 2, 2, 1	9.7
1.3	2:5:0:0	2, 2, 3, 0	11.1
3.1	3:3:1:1	3, 3, 1, 1	10.8
3.3	2:6:1:0	2, 2, 4, 1	10.6

^a Prophylactic

observed in our series; (3) no radiographic signs of chondrolysis, AVN and degenerative changes were observed, with the exception of the case of severe slip where the slip was reduced before fixation; (4) no difference in the primary outcomes was seen between the two types of screws and the number of threads that crossed the epiphyseal line.

Discussion

Internal fixation in SUFE has shown superior results in comparison to the other methods of treatment, in both clinical and radiographic terms as well as over the short and intermediate term [12, 13, 16, 18]. In situ fixation with multiple pins had been widely used in the past for the treatment of slipped upper femoral epiphysis [25]. However, poor results have often been attributed to the unrecognised penetration of the femoral head by the pins and subsequent chondrolysis [21, 24, 26]. Fixation with a single pin as opposed to multiple pins was preferred to avoid pin penetration and chondrolysis [11, 27]. Fixation with a single screw has become the preferred method of treatment due to problems encountered with pin fixation, such as pin penetration, pin breakage, complications of pin removal, epiphyseal growth over the pin/s, and slip progression [28, 29]. Furthermore, in-situ fixation of SUFE with a single screw is technically easier and has better results than the use of multiple pins [5, 6, 8–10, 24].

The position of the screw has been advocated to be of particular importance in the fixation of SUFE. The central–central position of the screw helps to avoid the inadvertent risk of joint penetration as well as providing a good anchor on the epiphysis. It is also the position that would help to minimise the risk of AVN as it avoids the postero-superior and the antero-inferior parts of the epiphysis, which are conduits for the blood supply to the epiphysis [30, 31].

Ward et al. [6] in their series reported eccentricity of screw placement to be related directly to an increasing length of time required for fusion of the physis. In the present study, no significant relationship between screw position and time to physeal fusion was found.

Carney et al. [32] in their series reported that slip progression is inversely related to the number of screw threads engaging the epiphysis on the postoperative radiograph. This finding was not reproduced in our study; possibly because all of the patients in our series had at least 8 mm of threads engaging the epiphyses. However, our results did agree with their finding of a lack of a correlation between screw position and time to physeal closure.

No changes in the lateral head-shaft angle (late slippage) were found when preoperative radiographs were compared with follow-up radiographs. Avascular necrosis was only observed in the one case of severe slip, which we believe,

albeit speculatively, was largely due to the disease process itself and the severe nature of the slip in the first instance. The low prevalence of AVN in our study is contrary to other reports in this field [7]. All patients had their surgery within 24 h of the time of presentation. This is more in keeping with findings of Phillips et al. [16] for the acute “unstable” slips.

Aronson and Carlson [7] stated in their study that the key variable regarding the risk of osteonecrosis is actually the time from the onset of symptoms to the time of surgery – and not the time from presentation to the time of surgery. We agree with this concept; however, this variable was not found to be of significance in our study. This discrepancy might be partially explained by the relatively small sample size in our study and the extra care which was taken during the fixation of SUFE in order to avoid incidental reduction of the slips that in turn may increase the risk of AVN.

The low incidence of chondrolysis observed in our series was partly due to minimal attempts being made during the advancement of the guide wires prior to the screw fixation as well as the tips of the screws being kept far away from the surface of the projected epiphysis on the image intensifier, especially for the eccentric positions of the screws. However, engagement of a sufficient number of screw threads across the physes was ensured in all cases.

The large number of acute slips in our study (16) was mainly observed in the latter years of the study. This observation coincides with the introduction of regular teaching by our department to the primary health service and accident and emergency departments emphasising the extra vigilance needed for the diagnosis of SUFE.

In our study, the main indications for prophylactic pinning were the presence of pain in the absence of radiological manifestations of SUFE and in those patients with endocrine disorders. These indications are supported in other research in this field [33].

The low frequency of the central–central position reported in our study can be explained by the following factors: (1) the surgeons’ apprehension of the risk of chondrolysis from making several attempts to advance the guide wire when trying to achieve the central–central position; (2) the surgeons’ endeavours to limit the fluoroscopic exposure to minimise radiation to the patient. There was no clear documentation of whether the surgeons lined up the guide pins in both planes prior to advancing the guide wire into the femoral head.

The removal of metalwork following the fixation of slipped upper femoral epiphysis remains an area of controversy. The potential risk from the removal of the metalwork can outweigh the potential benefit. This was the case in one of our patients who sustained a subtrochanteric fracture of the proximal femur shortly after he had his metalwork removed. We therefore agree with current

practice which favours retaining the metalwork except if it becomes symptomatic (localized pain) or if there is failure of the device, loosening and infection [34].

The limitations of the study are its (limited) numbers and the absence of a validated clinical scoring system. The small sample size can be explained by the fact that the condition is uncommon. Most studies in the field have comparable, small numbers [5–9, 11, 16, 18, 27]. The absence of clinical results can be explained by the paucity of documentation found in some of the clinical notes. This rendered the inclusion of a clinical scoring system invalid as it could not be applied to all of the cases in the series. A functional scoring system was not performed as the primary objective of this study was to evaluate the correlation between the position of the screw and the risks of AVN, chondrolysis and late slippage.

We did not assess the stability of the SUFE in this study, as was advocated by Loder et al. [8]. The stability of the slippage was not documented sufficiently in the majority of patients, especially for those patients in the early years of the study where the classification system (stable, unstable) was newly published. Although we agree with the importance of this classification, our study did not produce similar results with regards to the high incidence of AVN published by Loder et al. [8].

This study is one of the very few studies that have assessed the effects of varying screw placement in SUFE. It was a multi-centre study, involving two University hospitals, and reflects the results of the general setting of the National Health Service (NHS) in the UK.

Conclusions

The technique of a single hip screw fixation provides a good short- and intermediate-term outcome. In the present series, there were no reports of joint penetration or metal failure. No patient in this series demonstrated radiographic evidence of chondrolysis or AVN during the study period, with the exception of a severe slip where the slip was manipulated, reduced and subsequently fixed. Our results show that the positioning of the screw other than in the centre of the femoral head has the ability to provide physal stability and has no correlation with the timing to epiphyseal closure and the risks of avascular necrosis and chondrolysis in the cases of mild slip.

Central–central positioning of the screw has the potential advantage of avoiding the risk of epiphyseal vessel injuries and penetration of the hip. It therefore minimises the risk of AVN and chondrolysis, respectively. Based on these facts, we strongly recommend this position; however, in striving to achieve this position, multiple attempts may carry the potential hazard of joint surface penetration and

damage to capsular vessels, thereby – paradoxically – increasing the risk of chondrolysis and AVN. We therefore recommend, specifically for cases of mild slip, that other positions be considered if the optimal central position is not achieved in the initial attempt.

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