Hardware Complications Related to the Surgical Fixation of Slipped Capital Femoral Epiphyses

Edward Massa, Zacharia Silk, Nima Heidari, & Manoj Ramachandran*

Centre for Orthopaedics, Royal London Hospital, Barts and London Children’s Hospitals, Barts Health NHS Trust, London, United Kingdom

*Address all correspondence to: Manoj Ramachandran, BSc, MBBS, MRCS, FRCS, Department of Trauma and Orthopaedic Surgery, The Royal London Hospital, Barts Health NHS Trust, Whitechapel Road, London, E1 1BB, UK; Tel.: +44 207 377 2478; Fax: +44 207 377 7302; Manoj.Ramachandran@bartshealth.nhs.uk

ABSTRACT: Slipped upper femoral epiphysis is a disabling condition with an annual incidence of 2–13 per 100,000. In situ surgical fixation is the preferred initial treatment for both stable and unstable slipped capital femoral epiphysis (SCFE) cases. The main aim is to avoid further slippage and complications such as osteonecrosis and chondrolysis. The choice of medical implants in managing this condition has changed along the years from large nail-like devices to cannulated screws. The biomechanical properties of different fixation techniques have been studied. All implants have been associated with complications that can occur intraoperatively as well as in the early and late postoperative periods. This report examines a number of different implants used and identifies complications and ways on how to avoid such complications. It also looks at the complications directly related to medical implants in the management of SCFE. We looked at published literature in peer-reviewed journals describing the use of the different medical implants and the documented complications. We also examined literature that suggests ways on how to avoid and manage these complications. A review of the current literature is presented in this text.

KEY WORDS: hardware complications, slipped capital femoral epiphysis, SCFE, slipped upper femoral epiphysis, SUFE

I. INTRODUCTION

Slipped capital femoral epiphysis (SCFE) is a disorder of the proximal femoral epiphysis caused by weakness of the perichondral ring and slippage through the hypertrophic zone of the growth plate. It is most often seen in obese boys, aged 10–16 years, and up to 25% of cases are bilateral.

SCFE is traditionally classified into preslip, acute, chronic, and acute-on-chronic SCFE. Patients with a preslip may present with weakness, limping, or pain in the groin and knee on exertion of the affected limb. Acute slips are sudden displacement of the physeal with duration of symptoms of less than 3 weeks. On examination, the limb is externally rotated and shortened, and has a decreased range of motion secondary to pain. This type accounts for about 15% of all slips.1 If symptoms are present for more than 3 weeks, the slip is classified as chronic. Such cases present with months to years of pain in the hip, knee, or thigh with occasional worsening of symptoms. These patients have an antalgic gait and limited internal rotation, abduction, and flexion of the hip joint. Such patients account for around 85% of all cases.2 Some patients have chronic symptoms of SCFE but then
present acutely with worsening of pain. Such cases are classified as acute-on-chronic SCFE.

The more clinically relevant classification is based on stability. Loder et al. classified SCFE depending on whether the child can mobilize at all. If there is inability to walk on the affected side even with crutches, the SCFE is said to be unstable. This accounts for 5%–10% of all SCFE and 50%–60% of acute SCFE. If the child is able to bear weight, then it is deemed to be a stable slip, which accounts for 90% of cases. This classification is important as it predicts the likelihood of osteonecrosis of the femoral head. Loder et al. reported a 47% rate of osteonecrosis in unstable slips and 0% in stable slips. This drastic difference is probably secondary to vascular injury to the femoral head.

The severity of the slip is assessed radiologically. This is achieved by measuring the epiphyseal-shaft angle on the frog lateral view as described by Southwick. A slip angle of less than 30° is considered mild. An angle between 30° and 50° is considered moderate, whereas more than 50° is considered severe. Long-term follow-up showed that mild and moderate slips do well with in situ fixation, whereas severe slips do poorly with an associated low Iowa hip score.

Once SCFE is diagnosed, the mainstay of treatment is to prevent further slippage while avoiding the complications of avascular necrosis and chondrolysis. In suitable cases, this can be achieved nonoperatively with a hip spica. Surgical options include in situ fixation with single or multiple screws, or open reduction and internal fixation for more severe slips. All of the operative procedures involve fixation of the epiphysis to the metaphysis with surgical implants.

In a study by Riley et al., the overall complication rate associated with surgery was as high as 40%. In this cohort of patients (202 cases, 308 hips), hardware-related complications occurred in 26%. All cases had SCFE fixed with pins or screws. The most frequent complication was hip joint penetration with pins/screws (41 hips). Other complications included avascular necrosis (14 hips), chondrolysis (9), fracture (1), infection (1), further slippage (1), sciatic-nerve injury (1), and breakage of a screw (8). An additional procedure was required to correct pin-related problems in 18% of cases. In this review, we present a comprehensive summary of such complications and suggest methods to avoid them.

II. METHODS

A literature search was conducted using the PubMed and Ovid Databases. The PubMed search criteria used were as follows: (“epiphyses, slipped”[MeSH Terms] OR (“epiphyses”[All Fields] AND “slipped”[All Fields]) OR “slipped epiphyses”[All Fields] OR (“slipped”[All Fields] AND “epiphysis”[All Fields]) OR “slipped epiphysis”[All Fields]) AND (“bone screws”[MeSH Terms] OR (“bone”[All Fields] AND “screws”[All Fields]) OR “bone screws”[All Fields]) OR (“bone screws”[All Fields] OR “screw”[All Fields]) AND (“complications”[Subheading] OR “complications”[All Fields]). This identified 124 articles.

The Ovid search criteria were as follows: Epiphyses, Slipped/ OR Slipped Capital Femoral Epiphyses/ OR Epiphyses/su [Surgery] AND Postoperative Complications/ or Intraoperative Complications/ AND Internal Fixators/ or Bone Screws. This search identified 50 articles.

After removing duplicates and reviewing all of the abstracts for suitability, 31 articles were selected for use in this review. The conclusions and common features from these articles are summarized in the following text.

III. RESULTS

A. Joint Penetration

Hip joint penetration is an important complication of hardware insertion due to its association with chondrolysis. This may lead to subsequent hip pain and loss of function and there are a number of reports in the literature describing this.

During in situ fixation, the hip joint may be penetrated with either the guide wire or screws. In a case series by Jofe et al., patients who had evidence of chondrolysis following surgical stabilization of a SCFE all had evidence of joint penetration at surgery. In another study, Vrettos and Hoffman studied the etiology of chondrolysis in 14 patients. Six patients demonstrated radiological evidence of chondrolysis with persistent pin penetration. Another four hips had pin penetration...
without chondrolysis. The authors also found that pin penetration was more likely to result in chondrolysis in the anterosuperior aspect of the femoral head. There were two cases in which the joint was penetrated in the posterosuperior and posteroinferior aspect and these patients did not develop any chondrolysis. All patients with persistent pin penetration required pin removal.

While guide wire or screw penetration may occur during surgery, prompt identification of this is crucial to allow corrective action to be taken. In a study of 14 patients who had intraoperative joint penetration that was recognized and corrected, there was no joint pain from chondrolysis, suggesting that a single guide wire or screw penetration intraoperatively with immediate correction is not associated with increased risk of development of chondrolysis. This finding was also demonstrated by Vrettos and Hoffman, who could not find evidence of chondrolysis following transient pin penetration among their study group.

This complication is less common nowadays due to improved radiographic techniques, especially intraoperative fluoroscopy. Judicious use of intraoperative fluoroscopy during guide wire and screw insertion should ensure avoidance of this complication, provided orthogonal views are taken.

B. Impingement

Femoroacetabular impingement syndrome is a recognized complication of SCFE. Impingement either occurs because of the deformity of the femoral neck (femoral metaphysis and the superomedial acetabular rim) or is secondary to prominence of the screw head along the femoral neck. Goodwin et al. found that the limitation of hip movements after in situ fixation of moderate to severe slips is due not only to the degree of slip but also to the degree of screw head impingement against the acetabulum. This has its implications in pain and morbidity for the child and may compromise the anatomy of the femoral neck in an already deformed neck. They reported six cases of patients complaining of pain on sitting down and an altered gait with external rotation. Computed tomography scans revealed impingement of the screw head on the acetabulum. The resulting morbidity could include a functional limitation in hip movement, as well as impingement-related pain, labral degeneration, and damage to the articular cartilage, with the consequent development of secondary osteoarthritis of the hip. All of these cases required corrective surgery independent of whether the epiphysis was closed.

In a cadaveric model studying the effect of the femoral head screw position on range of motion and impingement, the hip flexion in moderate and severe SCFE in situ pinning was found to be about 70° and 50°, respectively, before the femoral screw head impinges on the acetabular rim. This could be improved to about 90° once the hip was externally rotated. Screw head impingement was also noted in internal rotation and abduction. Leunig et al. therefore proposed that for moderate to severe slips fixed by in situ cannulated screw fixation perpendicular to the physis, if the screw head lies lateral to the intertrochanteric line, the risk of impingement is minimal. If the screw head lies in the head neck area, the chance is increased. Finally, if the screw head lies in the head area, the risk of impingement is very high.

C. Proximal Femoral Fractures

Although rare, proximal femoral fractures have been reported as a direct or indirect complication after surgical fixation of a SCFE. Such fractures may either involve the femoral neck, placing the femoral head at risk of avascular necrosis, or may occur in the subtrochanteric region. Fractures have been reported to occur with the metal work in situ or following screw removal.

All femoral fractures reported were preceded by a significant trauma such as a fall. No reported femoral fractures occurred without any trauma.

1. Subtrochanteric Fractures

The incidence of subtrochanteric fractures in this cohort of patients is approximately 0.3%. Some case examples from the literature include a post-traumatic subtrochanteric fracture resulting from a cycling accident that followed in situ pinning of a mild SCFE with cannulated screw fixation. The child required screw removal and insertion of a cephalomedullary device to fix the fracture.
Cameron et al.\textsuperscript{19} reported five subtrochanteric fractures in 164 patients fixed with different hardware devices. All were transverse fractures and sustained after trauma. In all cases, the screw was inserted through the lateral femoral cortex below the level of the lesser trochanter.

Greenough et al.\textsuperscript{20} reviewed 83 hips and reported three such fractures. One fracture occurred 13 days after surgery with the devices in situ. The other two happened 4 weeks after screw removal. Other studies\textsuperscript{1,21} looking at long-term outcomes of SCFE pinning have reported subtrochanteric femoral fractures following trauma.

These fractures seem to have a direct correlation with drill holes or defects in the lateral cortex. Canale et al.\textsuperscript{22} reported four subtrochanteric fractures through unused drill holes. This accounts for only 1.4% of patients studied in this series over a 10-year period. Since all of these fractures occurred through drill holes, avoiding extraneous screw holes is the best possible way to avoid such fractures. Once subtrochanteric fracture occurs, immediate open reduction and internal fixation with a compression hip screw device is the suggested procedure.\textsuperscript{22}

Chiseling the lateral femoral cortex to facilitate removal of metalwork predisposes to subtrochanteric femoral fractures.\textsuperscript{23,24} This occurs more commonly if the entry point is below the lesser trochanter.\textsuperscript{25} Canale et al.\textsuperscript{22} suggest partial weight bearing for 3–6 weeks after difficult removal of screw with significant bone chiseling to avoid this complication.

\section*{2. Femoral Neck Fractures}

These fractures are less common than subtrochanteric fractures and appear to occur earlier than subtrochanteric fractures when the metalwork is still in situ. Possible causes as suggested by Baynham et al.\textsuperscript{26} include thermal injury caused by reaming of the femoral neck before screw insertion. In contrast, Koval et al.\textsuperscript{27} reported a possible stress fracture in someone who had no reaming of the proximal end of the femur. None of these fractures occurred through the bone-screw interface.

An anterior femoral cortex entry point increases the risk of femoral neck fracture,\textsuperscript{28} while an entry point on the lateral cortex can predispose to a subtrochanteric fracture.\textsuperscript{25} Although the entry point is considered to be a stress riser, biomechanical studies to determine the weakness of the surrounding bone once a pin is introduced are not available. Screws should be placed in the relatively safe zone above the lesser trochanter.\textsuperscript{26,28}

\section*{D. Guide Wire Complications}

Complications relating to the use of guide wires include intraosseous and intraarticular breakage, as well as joint penetration as was discussed earlier in this article. In their series, Robb et al.\textsuperscript{29} reported six cases of guide wire breakage (n=5) or damage (n=1) during insertion of cannulated screws. The guide wire used was 23 cm long with a 2 mm diameter. These wires were either retrieved or left in situ with no documented complications and subsequent uneventful recoveries. Notching of the wire was also reported in one of the cases. The authors also reported that the guide wire may bend during insertion when obtaining a frog leg lateral radiograph intraoperatively.

Such complications led the Medical Devices Agency to issue a safety notice in 2001. The agency made a number of recommendations including the utilization of single-use guide wires as well as serial image intensifier image capturing, during the insertion of a cannulated screw over a guide wire in order to observe any wire bending or notching and to prevent joint penetration.\textsuperscript{30} In their study evaluating pin penetration into the hip joint, Lehman et al.\textsuperscript{31} reported a 2% incidence rate of guide wire breakage. Riley et al.\textsuperscript{1} also reported guide wire breakage with migration of the fragment into the hip joint.

Ilizallituri et al.\textsuperscript{32} described the arthroscopic retrieval of a broken guide wire that migrated into the hip joint during SCFE pinning. Since such a complication can have significant morbidity, it is important to retrieve the fragment with minimal morbidity. Arthroscopy is a relatively safe procedure that is both therapeutic and diagnostic. During retrieval, the authors examined the cartilage surface of the femoral head to visualize whether any cartilage damage was done. This was not the case and the guide wire was safely removed with no postoperative complications.
E. Screw/Pin Removal

Hardware removal in children is a controversial topic. There is no evidence in the current literature to support the practice of routine implant removal in children. Notably, there is little literature opposing the routine removal of such implants.33 There are no prospective studies evaluating the long-term implications of hardware retention in children. The anecdotal evidence is that the rate of malignancy in such cases is very low. Delayed or low-grade infections have rarely been reported. The reasons for removal include difficulty with arthroplasty surgery later on in life. The longer the screws are kept in situ, the more bone will grow over the screw heads and the more difficult they are to remove if necessary. Pins left in situ can act as stress risers28 leading to femoral fractures after trauma. Some studies report trochanteric bursitis34 from retained pin heads, which can be significant and warrant removal.35

In a survey specifically looking at a surgeon’s decision to remove or retain metalwork, Loder and Feinberg36 concluded that nonpediatric orthopaedic surgeons tend to remove metalwork in children more frequently than pediatric surgeons. This is mainly due to the risk of problems in arthroplasty surgery in later life.37

In a systematic review by Raney et al., 871 children had hardware removed. Of these patients, 110 (13%) had SCFE. Complications from SCFE hardware removal accounted for 34% (37 of 110 SCFE cases) of the total hardware removal complications.33 Similarly, Jago and Hindley35 reported a 27% rate of complications from hardware removal in SCFE.

Complications from metalwork removal include lengthy procedures, cortex chiseling, and failure of removal of the screw. The suggested time of removal of metalwork is 2 years after the insertion of the fixation device when the physis is closed.24

Many of the complications encountered are specific to a particular device, as discussed in the next section. Some devices have been deemed to be unsafe in the use of SCFE fixation, as is the case for the ASIF epiphysiodesis screw. In a report by Larsson and Friberg,38 13 of 23 patients had complications during extraction. These complications included broken screws, screws embedded in the bone, and extensive chiseling. For this reason, the ASIF epiphysiodesis screw is not recommended for use in SCFE.

Other implants have been promoted for use in SCFE fixation, specifically because their removal is not associated with a high complication rate. One such device described by Gruber et al.39 is an 8.0-mm cannulated screw with a hexagonal male head (Smith & Nephew Richards Medical, Memphis, Tennessee). The prominent head allows a hexagonal female screw driver to fit perfectly over it. A locking pin is inserted through the screw driver to lock the screw and screw driver together avoiding the complications of stripping the head during removal. The screw tip is self-tapping and has reverse cutting flutes that help in cutting through bone that grows around the threads. Gruber et al. showed that using this technique and the correct screw reduces the complication rate of screw removal after SCFE pinning.

A number of complications related to the removal of metalwork have been reported by Ilchmann and Parsch24 when using the Stryker ASNIS III. They recommend not using these screws for SCFE fixation because of the high rate of complications related to the removal of these screws, which is discussed later in detail.

These studies highlight the importance of choosing the correct screw to use in SCFE and having the correct removal kit when needed.

F. Loosening

Windshield-wiper loosening of the screw was described by Maletis and Bassett.40 They reviewed patients treated with titanium screws for SCFE fixation retrospectively. Three of 18 patients reviewed at 1-year follow-up had loosening. In all cases, the screw was protruding to >1.5 cm from the femoral anterolateral cortex. This could be the possible reason for loosening of the screw. Hip motion could possibly have resulted in backing out of the screw. They recommend placement of the head screw within 1.5 cm of the anterolateral cortex of the femur.

G. Comparison of Different Fixation Devices

The gold standard treatment of SCFE is percutaneous fixation with one cannulated screw.21 In this
report, from the 44 children (48 hips) reviewed at an average of 3 years of follow-up, 44 hips were rated as excellent according to the clinical criteria by Heyman and Herndon and radiographic parameters by Boyel et al. Avascular necrosis only developed in one case and this child had an acute slip. Chondrolysis did not occur in any case. The other complications included a subtrochanteric fracture in one patient and further slippage in another two patients.

A number of other implants are available and can be used as single or multiple fixation devices. We discuss some of these below.

1. **K-Wire Fixation**

In a retrospective review of 29 patients who had a SCFE treated with K-wire fixation, 62.1% had an excellent result (18 patients), 31.1% were classified as good (9 patients), 3.4% as fair (1 patient), and 3.4% as poor (1 patient) according to the Heyman and Herndon Classification. No patients showed slip progression at follow-up. Eight patients required revision and one patient developed avascular necrosis, but no patients went on to develop chondrolysis in this series. No complications were reported during the surgery or during removal of the K-wires. This shows that K-wires can safely be used for SCFE fixation.

2. **Type of Screw**

For a short while, titanium cannulated ASNIS III screws by Stryker were used for the treatment of SCFE. Despite their relative ease of insertion, an unfortunately high rate of complications arose during ASNIS screw removal. This was due to the inadequate torque strength of the screw head Allen socket, which could not overcome the strength required to back the screw out of the healed bone. Damage to the screw head meant patients required more bone debridement to allow the screw to be removed, therefore increasing the risk of femoral fractures.

In terms of retrieval time alone, stainless steel screws have been shown to be superior to titanium screws. In addition, a fully threaded cannulated screw as opposed to a partially threaded one has been reported to be easier to remove due to the fact that no reverse cutting mechanism is required. While a greater surface area of contact between the bone and the fully threaded screw requires a higher initial torque to disengage it from the bone, the use of a hexagonal screw head instead of the Allen socket may be more resistant to damage.

3. **K-Wires Versus Screws**

In a biomechanical study using an animal model, Druschel et al. compared the strength and stiffness of the following implants: 1) a single 7.3-mm stainless steel AO screw (Synthes, Solothurn, Switzerland), 2) a single dynamic telescopic screw, 3) 3 × 1.6-mm K-wires, and 4) 3 2.0-mm K-wires. No difference was demonstrated between implants in relation to fatigue failure. There was, however, a statistically proven biomechanical benefit in using the 3 × 2.0-mm K-wire, which was both the strongest and stiffest construct compared to the other implants analyzed.

Maus et al. compared in situ fixation between K-wires and cannulated titanium screws. They looked at 46 patients with grade I and grade II SCFE. Patients were followed-up for 1 year and clinically assessed using the same criteria used in the study by Druschel. Magnetic resonance imaging was used to assess the vascularity of the head before and after fixation. At clinical follow-up, the two groups (K-wires versus titanium screws) showed comparable results in clinical scores. Nevertheless, patients who had K-wire fixation showed a higher revision rate (50%) and a lower rate of abnormal gait in comparison to patients treated with titanium screws. There was one reported case of chondrolysis within the K-wire fixation group and no complications were observed when removing K-wires. In contrast, there was failure of removal in 4 of 10 cases with titanium screws. The author suggests using cannulated screws because of a decreased revision rate but would opt for stainless steel rather than titanium because of a decreased removal complication rate.

4. **Dynamic Screw Fixation**

Hackenbrooch et al. reported the use of a dynamic screw fixation (DSF) allowing dynamization...
of the epiphysis with no complications. The technique of DSF is applicable using a long cannulated screw with a short thread. DSF is easy to handle, provides sufficient long-term fixation of the epiphysis, does not promote premature closure of the epiphysis, and has few complications. In this case series, 29 hips with mild SCFE and 34 hips were prophylactically nailed using DSF. The authors showed good stabilization of the epiphysis with no growth disturbance of the femoral neck.

5. Steinmann Pin Fixation

Steinmann pin use in SCFE has been reported by Lehmann et al. Fixation is achieved with two to three pins (2.3 mm diameter) placed in parallel. These have an 8-mm thread at the medial end that is screwed into the femoral head. There was a progressive decline in the number of pins used. Initially three pins were used, but the practice changed to using two pins instead. Pins were cut approximately 1–2 cm from the lateral femoral cortex. In this study, 69 cases with 89 slips were operated on. Acute surgical complications occurred in 10 hips. In three hips, there was joint penetration detected on postoperative radiographs and needed reoperation. In five cases, the pins were too long and protruded out of the lateral cortex and thus needed a second procedure to shorten the pins. Two patients received antibiotics for a superficial wound infection. All patients had a good long-term outcome from surgery. The patients were allowed to partially weight bear postoperatively using crutches for 4–6 weeks. The pins were removed after closure of the femoral physis. Another three cases needed further surgery later, with one sustaining a femoral fracture post-pin removal, one needing restabilization, and another needing leg lengthening. In the long-term, one case had avascular necrosis but there were no reported cases of chondrolysis or slip progression. The main advantage in using Steinmann pins as suggested in this report is growth of the femoral neck while the pins are in situ and prevention of further slippage improving biomechanics, remodeling, and prevention of leg length discrepancy. This has led implant companies to design growing screws as an option for treating SCFE, although there are no reports as yet of their efficacy and long-term results.

6. Hansson™ Hook Pins

The Hansson pin system was developed at the University of Lund in Sweden (Stryker). The main advantage in SCFE fixation is that the hook prevents loosening of the femoral head to the neck. Concurrently, the longitudinal growth of the femoral neck retracts the pin stabilizing the femoral head.

In an early report by Hansson, 75 hips in 38 cases were followed-up prospectively for 6 years. One patient had a superficial wound infection. Some patients experienced crepitations between the fascia lata and the pin but this resolved with growth of the femoral neck embedding the pin in bone. Ten of the 37 slipped hips that were fixed had premature closure of the epiphysis, while 12 hips had no radiological evidence of femoral neck growth.

A radiolucent zone developed in most hips with a 2- to 8-mm wide zone reported in two cases. One case (with an 8-mm zone) required removal and repositioning of another hook pin. The other case was left in situ as the femoral neck was still showing evidence of growth.

Nineteen hips have had the pins removed with no reports of breakage of the device or difficult in extraction.

IV. CONCLUSION

Treatment of SCFE with implants is not without its risks and complications, including insertion, retention, and removal of the implants. This review summarizes the current evidence on the risks and complications observed in patients who undergo pinning as the mainstay of fixation in SCFE.

REFERENCES


