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# In situ screw fixation of slipped capital femoral epiphysis with a novel approach: a double-cohort controlled study

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**Abstract**
*Purpose* In situ fixation for mild to moderate slipped capital femoral epiphysis (SCFE) remains an acceptable treatment methodology in most centers. Satisfactory fixation results have been reported with the procedure using either the fracture table or radiolucent table, both of which allow the hip to be imaged during the procedure. The position of the pin within the center of the femoral head is important to secure adequate fixation of the capital femoral epiphysis and prevent further slippage with minimal risk for articular penetration and avascular necrosis (AVN) or chondrolysis.
*Methods* We describe a pre-operative planning technique to determine the pin-entry point for percutaneous pinning of SCFE on a radiolucent operating table. A retrospective review of patients who underwent in situ screw fixation with the usage of a cannulated screw on a radiolucent table or fracture table over a 6-year period was conducted.
*Results* The pin-entry point with this technique was reliable in 92% of procedures and comparable in both accuracy and complications to in situ screw fixation on a fracture table. In situ screw fixation on a regular radiolucent table was straightforward and required significantly less surgical time than on the fracture table ($P = 0.01$). It was also more efficient during a bilateral procedure, as it required only a single preparation and draping of the patient.
*Conclusion* This pre-operative planning technique for deciding the starting point on the proximal femur is helpful in executing an accurate in situ screw fixation of hips with SCFE.

**Keywords** In situ epiphysiodesis · Slipped capital femoral epiphysis

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## Introduction

In situ screw fixation for slipped capital femoral epiphysis (SCFE) remains a commonly utilized treatment methodology [1–8]. Several studies have reported good results of fixation with the use of a fracture table for in situ fixation and epiphysiodesis [1, 4, 9, 10]. With the fracture table, the hip position may not have to be moved intra-operatively to visualize the anteroposterior (AP) and lateral radiographic views, thereby, likely reducing the risk of further displacement of the slipped physis. Notable disadvantages of using a fracture table include; longer set up time, repetitive maneuvering of the image intensifier for biplane imaging, and relative difficulty in obtaining clear lateral images in obese patients [11]. In cases of bilateral SCFE, while using the fracture table technique, it is necessary to change the table positioning and drape the surgical field a second time, leading to further delay in operative time. In case of adolescents with higher body mass index (BMI) ($\gtrsim 30$), transfer from a stretcher to the fracture table can be difficult and, in rare circumstances, the fracture table may not accommodate the size of the patient [11]. It is also possible that the weight of the suspended leg in some instances may further displace the neck and metaphysis in relation to the capital physis. These concerns led some of the authors to evaluate methods for in situ pinning that did not require a fracture table.

In a previous study, Blasier et al. [11] evaluated stable slips over a 10-year period treated by single screw fixation on either a radiolucent (29 hips) or fracture table (36 hips). They found that the surgical time was significantly longer on the fracture table (38.55 min) compared to the radiolucent table (24.8 min, $P < 0.05$). The percentage of deviation of the screw from the midpoint of the epiphysis was not significantly different on either the AP or lateral radiographs ($P > 0.10$). Interestingly, the complication rate associated with either procedure or the need for further surgery was not reported. Other reported advantages of the radiolucent table include minimal maneuvering of the image intensifier and free movement of the limb under image intensification to evaluate pin placement [11]. Potential disadvantages of the radiolucent table for the treatment of SCFE include the need for an assistant to hold and manipulate the limb, the need to reposition the limb to obtain a lateral view, which may risk further motion through the physis, and the possibility of occasionally bending the guide pin during limb repositioning [11].

Lee and Chapman [12] initially described a technique for determining skin-pin entry in stable SCFE on a radiolucent table. In the 13 patients of the series (15 hips, mean age 10.5 years), all pins were positioned correctly and none of the patients required additional skin incisions. Additionally, no complications were specifically reported in relation to the gentle maneuver of flexion, abduction, and external rotation required for obtaining the frog-leg lateral after pinning. They commented that pinning was much easier without the need to transfer these often obese (all patients were over the 95th percentile of weight for age) patients onto a fracture table. Despite the reported accuracy of this technique for evaluating the skin entry site for the guide pin with a radiolucent table, multiple line drawings on the skin seem to be necessary. This may prove to be more challenging in the obese patient. We propose a similar but simpler technique for the accurate pinning of SCFE based largely on planning from the pre-operative AP and lateral radiographs. The purpose of this study was to describe a pre-operative planning technique and surgical execution for percutaneous in situ epiphysiodesis with the usage of a cannulated screw in SCFE on a radiolucent table and to compare the surgical times and accuracy of pin placement with in situ screw fixation on a fracture table.

## Methods

This was an institutional review board (IRB)-approved non-randomized double-cohort retrospective review of consecutive patients with SCFE treated with in situ epiphysiodesis. One group was treated by in situ screw fixation on a radiolucent table and the other by in situ screw fixation on a fracture table. Patients who had in situ fixation for SCFE, by fellowship-trained pediatric orthopedic surgeons, over a 6-year period (March 1997 to November 2002) were identified. This time period was specifically chosen as, at that time, our surgeons were nearly equally split with regard to their preference of operating table. Seven orthopedic attendings were involved in these cases and the choice of operating table (fracture vs. radiolucent) used was based on surgeon preference.

The demographics of the patients gathered included: gender, age, weight, side involved, clinical stability [10], slip grade, and slip angle. The time required to position and prepare the patient on either operating table plus the duration of surgery (total operating time) and the duration of radiation exposure were obtained from operative records.

## Surgical techniques

### Fracture table method

In this technique, the patient is transferred to the fracture table and the involved leg is fixed in slight internal rotation with a traction boot. The well leg is positioned in hip abduction to allow room for the image intensifier to be positioned for both AP and lateral views. No specific attempt is made to reduce the position of the slip with any excessive rotation.

The screw trajectory is planned on both AP and lateral image intensifier projections, drawing a line on the thigh for each view. A guide pin with the image intensifier is used to establish these lines. The intersection of these lines on the anterolateral thigh marks the guide pin insertion site through the skin. The trajectory is planned to attempt a central pin position within the femoral epiphysis on both AP and lateral views, crossing the physis at a 90° angle [4].

### Radiolucent table method

The patients for this technique are transferred to a radiolucent table in the supine position. The image intensifier is maintained in position for the standard AP projection with subsequent positioning of the leg into abduction and external rotation (frog position) to obtain a lateral view of the proximal femur. The trajectory planning for the AP view of the hip is the same as for the fracture table method, with a line drawn on the anterior thigh and groin. The intricacy of this technique, however, involves planning the trajectory in the lateral plane. To accomplish this, a series of measurements are made based on the pre-operative AP and lateral radiographs. The trajectory (line A) is first drawn on the pre-operative AP radiograph (Fig. 1a). A similar line (B) is drawn on the pre-operative lateral view, noting the position ($P_L$) of the intersection of this line with the anterior aspect of the femoral neck (Fig. 1b). The perpendicular distance of this intersection point to the midpoint of the lesser trochanter is measured (L). This distance is transferred to the AP image as a transverse line perpendicular to the femoral shaft measured from the mid-lesser trochanter. The intersection of the perpendicular line with that of the AP trajectory line defines the starting point ($P_A$) on the AP view of the femoral neck for the guide pin (Fig. 1c). The pin angulation on the lateral projection is also estimated from the pre-operative lateral view to determine the degree of anterior to posterior angulation (S°) of the guide pin (Fig. 1b). With the angulation on both AP and lateral pre-operative projections, as well as the starting point location on the anterior femoral neck, the plan for pin placement can be established without intra-operative manipulation of the leg. The skin penetration site is estimated and modified as needed to achieve the above criteria for the starting point on the femoral neck and lateral plane anterior to posterior angulation. Once the pin is advanced into the femoral head to stabilize the physis, the cannulated screw driver is placed over the guide pin down to the bone to prevent pin bending and the leg is slowly abducted while checking the pin position with the image intensifier. Care must be taken to prevent the pin from bending due to soft tissue stretching and possible mild leg rotation. Adjustments are made as required and confirmed by leg rotation (with or without additional rotation of the image intensifier) to obtain a full lateral view of the hip. With the guide pin appropriately positioned, a cannulated

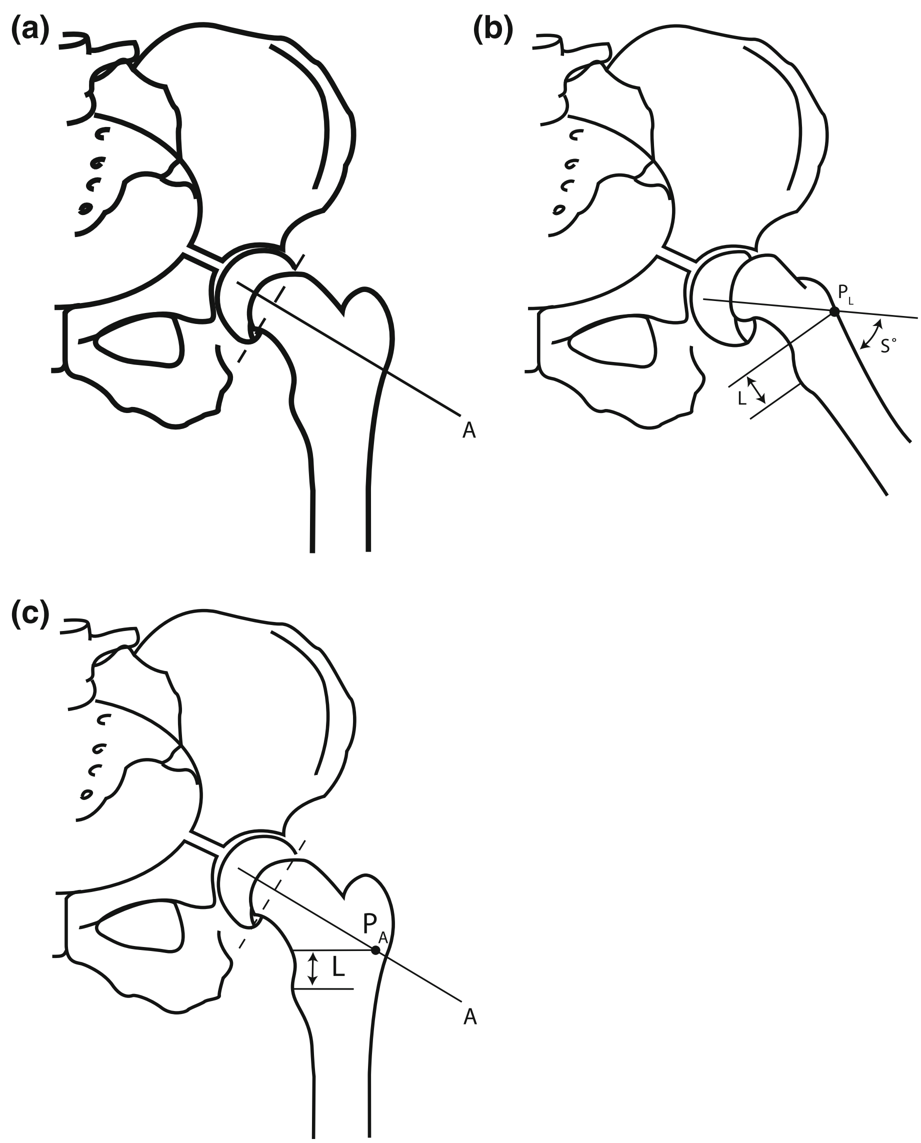


**Fig. 1** **a** Anteroposterior (AP) drawing of a hip. The AP screw trajectory is denoted by a line (*A*) that is drawn through the center of the capital femoral epiphysis towards the lateral margin of the femur. **b** Drawing of a frog lateral view of the hip. The lateral screw trajectory is represented by a line (*B*) which passes through the center of the capital femoral epiphysis in a perpendicular direction towards the anterior aspect of the femoral neck ($P_L$). The perpendicular distance of $P_L$ to the middle of the lesser trochanter is denoted by *L*. The slip angle ($S^{\circ}$) between *B* and the femoral shaft is shown. **c** Line drawing (*AP view*) of the hip showing the starting point for the procedure (*P*). This will be the perpendicular distance (*L*) away from the mid-lesser trochanter

screw is now placed over this, stabilizing and fixing the epiphysis (Fig. 2).

Accuracy of pinning

The accuracy of pin placement with the epiphysis was graded as A, B, or C using templates on the AP and frog lateral radiographs; the templates were designed for this study to evaluate the distance of the tip of the screw from a "bulls-eye" pinning (Fig. 3). "A" accuracy of pinning implied that the pin was placed within the central 50% of the physeal width, with the screw tip 5–10 mm across the physis, at least 5 mm from the subchondral bone, and at an angle of 70–90° to the capital physis. "B" accuracy of pinning occurred when the pin was placed outside the "A" area but not in the "C" area. This was considered to be an area containing the central 75% minus the central 50% of the physeal width, with the screw tip less than 5 mm across the physis or less than 5 mm from the subchondral bone, and at an angle of 50 to 90° to the physis. "C" accuracy of pinning described screws placed outside the central 75% of the physeal width, less than 2.5 mm of screw tip across the physis, less than 2.5 mm from the subchondral bone, or at an angle less than 50° to the physis.

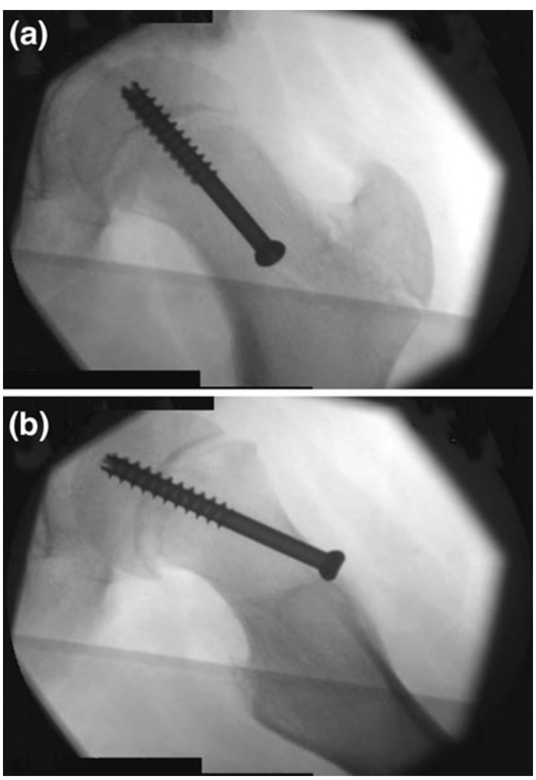


**Fig. 2** **a**, **b** Intra-operative fluoroscopic AP view of a left hip with a slipped capital femoral epiphysis (SCFE) showing a cannulated screw inserted on a radiolucent table

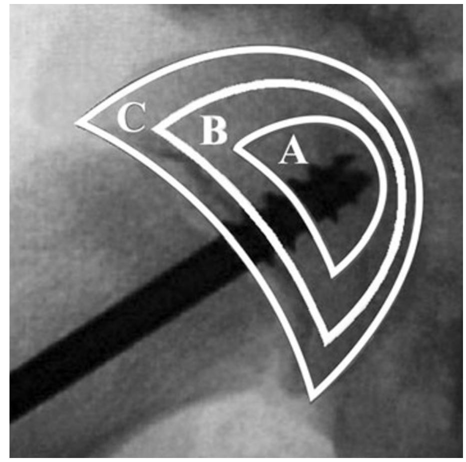


**Fig. 3** Radiograph of a femoral head showing the *templates* used to assess the accuracy of pinning. See text for details

Analysis of variance (ANOVA) was used to determine whether the image intensifier time, surgery time, and accuracy of screw placement differed for the radiolucent table and fracture table groups. Alpha was set at $P \leq 0.05$ to declare significance.

## Results

One hundred and six patients (149 SCFEs) were included in the study. There were 70 males and 36 females, with an average age of 12.5 years (range 8–19 years) at the time of surgery and an average follow-up time at last visit of 1.1 years (range 6 months to 5.5 years). Thirty-six hips were fixed on a fracture table and 113 on a radiolucent table. Eighty-nine percent (134) of hips had slips that were classified as stable, whereas 10% (15) were unstable. Of the 134 hips with stable SCFE, 101 (75%) were treated on a radiolucent table and 33 (25%) on a fracture table. Of the 15 unstable hips, 12 (80%) were treated on a radiolucent table and three (20%) were treated on a fracture table. There were 52 unilaterally involved left and 41 right SCFEs. Twenty-six of these unilateral procedures were done on a fracture table and 67 on a radiolucent table. Twenty-eight patients (56 hips) were fixed in a single bilateral procedure. Of the hips that were fixed in a single-stage bilateral procedure, ten were fixed on a fracture table and 46 on a radiolucent table.

The total operating time for the hips treated on a fracture table was significantly greater than on the radiolucent table for both unilateral ($65.6 \pm 11.5$ min vs. $50.8 \pm 15.7$ min; $P < 0.05$) and bilateral procedures ($93.3 \pm 10.2$ min vs. $64.6 \pm 20.6$ min; $P < 0.05$) (Fig. 4). There was no significant difference in image intensifier time required for screw fixation on either the radiolucent table

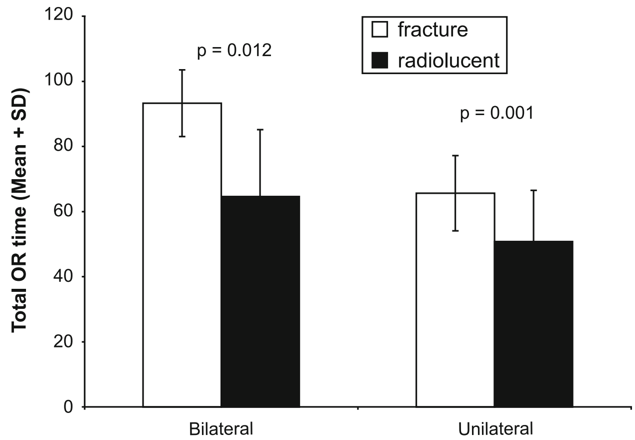


**Fig. 4** Graph showing a comparison of the mean total operative times for unilateral and bilateral hip procedures utilizing the radiolucent and fracture tables

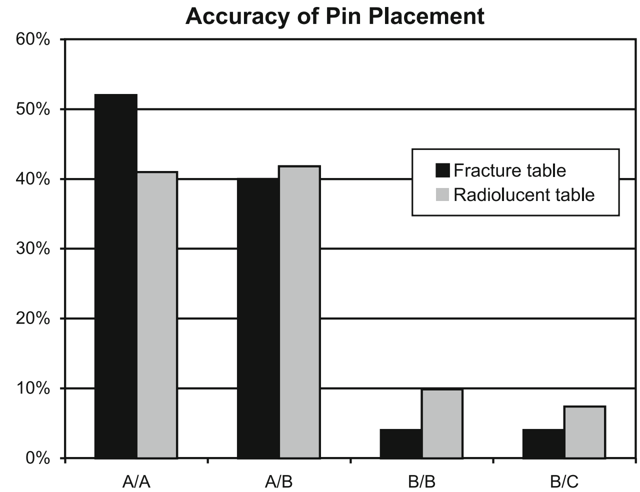


**Fig. 5** Graph depicting the distribution of the accuracy of pin placement for radiolucent and fracture tables (no significant difference in the distribution $P > 0.05$). *A/A* indicates pinning of A accuracy in both AP and lateral projections. A grading of *A/B* has pin placement of grade A in one plane and grade B in the other. *B/B* indicates pinning of B grade in both planes. A grading of *B/C* has pin placement of grade B in one plane and grade C in the other

($0.76 \pm 0.87$ s) or the fracture table ($0.95 \pm 0.63$ s) ($P = 0.43$).

The distribution of the accuracy of screw placement was not significantly different for the two methods in either the AP or lateral planes ($P = 0.62$, Fig. 5). The majority of screws placed in both table groups were either graded as A in both AP and lateral planes or A accuracy in one plane and B accuracy in the other (92% fracture table and 83% radiolucent table fell in these two categories). Four percent of screws placed on a fracture table and 10% of screws placed on a radiolucent table were inserted with B accuracy of placement in both the AP and lateral planes. Of the screws that were least accurately placed (B accuracy in the AP plane and C accuracy in the lateral plane), four percent were on a fracture table and 7% on a radiolucent table.

Three hip screws in the radiolucent table group (2.6%) versus four (3.5%) in the fracture table group were subsequently removed ($P > 0.05$). These screws, except for one in the radiolucent table group, were removed at the end of the growth period, at which time each patient underwent a corrective osteotomy for angular and/or rotational abnormalities. One patient in the radiolucent group, a 14-year-old with severe hypothyroidism, sustained a fall two weeks after in situ epiphysiodesis, which resulted in movement of the slip site. This screw was subsequently revised and the fixation reinforced with a second screw.

## Discussion

Studies have shown that the overall rate of complications increases with the number of pins or screws inserted [3, 13, 14]. Attention has, thus, been directed toward single-screw fixation in stable SCFE. Nevertheless, both single and multiple fixation techniques are associated with risks. Avascular necrosis (AVN), chondrolysis, loss of fixation, subtrochanteric and femoral neck fractures, pin penetration, pin breakage, pin extrusion, and infection have been reported as complications [8, 15–21].

The technique for pin insertion on the radiolucent table allows for accurate screw placement for the treatment of SCFE. In the present study, the average surgical time for screw insertion in a hip on the radiolucent table was 31.0 min. In a similar study, Blasier et al. [11] reported a similar mean surgical time of 24.8 min for single-screw fixation on a radiolucent table. One of the main pre-requisites to successful execution of fixation is the calculation from the pre-operative radiographs of the slip angle (S°) on the lateral view and the determination of the starting point on the anterior femoral neck in the AP plane. Once this has been accomplished, the procedure can be performed under AP image intensifier control. This technique does require experience in estimating the skin entry site for the guide pin to reach the appropriate starting point on the anterior aspect of the proximal femur.

In obese patients, lateral fluoroscopic visualization of the hip is sometimes poor with the patient positioned on the fracture table. On a radiolucent table, manipulation of the limb to obtain frog lateral images of the hip is not only more expeditious, but often provides a higher quality image on the lateral view than that obtained on a fracture table. However, manipulation of a large leg risks bending even the most stout guide pins. Special care is required to avoid bending the guide pin in all cases, especially as the girth of the leg increases. Protected rotation of the leg while holding the guide pin at the site of skin insertion will allow adequate external rotation to see the lateral trajectory. Forceful manipulation into the flexion–abduction frog position should be avoided while the guide pin is in place. If required, slight rotation of the image intensifier may aid in obtaining the full lateral view.

One of the other concerns with the radiolucent table is the need to manipulate the limb with a potentially unstable SCFE, leading to increased risk of AVN. The counter argument, however, is that it may be less traumatic to the physis to perform protected gentle rotation of the leg with it fully supported on the operating table than to suspend the full weight of the leg in a traction boot on the fracture table. Additionally, with proper planning of the pin/screw trajectory, the guide pin should be safely capturing the epiphysis before the need to rotate the leg. In other studies, gentle rotation on a radiolucent table to obtain the frog-leg lateral radiographs in patients with a stable SCFE was not associated with higher rates of AVN or chondrolysis [12]. In the present study, we did not encounter any cases of AVN at a mean follow-up of 1.1 years (range 6 months to 5.5 years).

In conclusion, both approaches, when conducted well, can offer safe and reproducible means of pinning hips with SCFE. Ultimately, the surgeon will need to choose the approach on a case-by-case basis. The pre-operative planning technique that has been outlined for calculating the starting point on the proximal femur is useful particularly if the radiolucent table method is preferred. It easily allows one to calculate the starting point on the anterior femoral neck for appropriate screw placement on both AP and lateral projections.



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