The Universal Entry Point with oblique screw is superior to fixation perpendicular to the physis in moderate slipped capital femoral epiphysis

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Abstract
Purpose: Stable slipped capital femoral epiphysis (SCFE) is often treated with in situ pinning, with the current gold standard being stabilization with a screw perpendicular to the physis. However, this can lead to impingement and a potentially unstable construct. In this study we model the biomechanical effect of two screw positions used for SCFE fixation. We hypothesize that single screw fixation into the centre of the femoral head from the anterior intertrochanteric line (the Universal Entry Point or UEP) provides a more stable construct than single screw fixation perpendicular to the physis with an anterior starting point.

Methods: Sawbone models of moderate SCFE were used to mechanically test the two screw constructs and an unfixed control group. Models were loaded to failure with a shear load applied through the physis in an Instron mechanical tester. The primary outcomes were maximum load, stiffness and energy to failure.

Results: Screw fixation into the centre of the femoral head from the UEP resulted in a greater load to failure (+19%), stiffness (+13%) and energy to failure (+45%) than screw fixation perpendicular to the physis.

Conclusions: In this sawbone construct, screw fixation into the centre of the femoral head from the UEP provides greater biomechanical stability than screw fixation perpendicular to the physis. This approach may also benefit by avoiding an intracapsular entry point in soft metaphyseal bone and subsequent risk of impingement and loss of position.

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Introduction
Slipped capital femoral epiphysis (SCFE) is the most common hip disorder in adolescents with a reported prevalence of up to 10.8 per 100 000 children.1 Furthermore, children are presenting at a younger age and the incidence of SCFE is rising, possibly potentiated by the current epidemic of childhood obesity.2-4 In situ pinning is a commonly performed method of treatment for stable slips due to the low associated risk of avascular necrosis.5,6 The current gold standard is to perform the fixation with a screw perpendicular to the physis.7,8 This necessitates an increasingly anterior and proximal entry point with increasing severity of slip, which can result in an intracapsular entry point in soft metaphyseal bone, impingement of the screw head on the acetabular rim and loss of fixation. Subsequent screw head impingement in hip flexion activities, such as sitting or riding a bicycle, could also cause painful bony erosion.7,8

We have termed a starting point of the middle of the anterior intertrochanteric ridge as the Universal Entry Point (UEP); this can be utilized in all in situ fixation of stable SCFE. The UEP avoids the inherent risks of an intracapsular entry point in soft metaphyseal bone with potential subsequent impingement and loss of fixation. Utilization of the UEP results in screw fixation oblique to, rather than perpendicular to, the physis. The utility of the UEP is based on the authors’ observations and those of others published in the literature. Cadaver studies with simulated SCFE have shown screws with an oblique trajectory reduces impingement.9 One clinical series found that the use of a lateral entry point and oblique screw placement...
provided adequate fixation with no screw related complications.\textsuperscript{10} In a subsequent \textit{ex vivo} study simulating moderate SCFE in porcine femurs, the lateral entry point and oblique screw position was found to have comparable mechanical performance as a screw positioned perpendicular to the physis with an anterior entry point.\textsuperscript{11} We prefer an entry point in the anterior intertrochanteric ridge as this allows proximal fixation in a ridge of thick cortical bone and avoids the potential pitfall of subtrochanteric fracture that can be associated with a lateral entry point, especially at or below the level of the lesser trochanter.\textsuperscript{12} In this study, we hypothesize that single screw fixation into the centre of the femoral head from a starting point of the middle of the anterior intertrochanteric ridge (the UEP), would provide a more mechanically stable construct than single screw fixation perpendicular to the physis.

**Methods and materials**

In total, 32 synthetic femora (#1161 Sawbones, Washington, USA) moderate SCFE models were obtained. The femoral heads of these specimens were osteotomized across the physeal scar and the head repositioned with the use of silicone (Selleys Roof & Gutter Silicon, Selleys Australia, Padstow, NSW, Australia) to simulate the immature physis. Tile spacers were used to create a physis of uniform thickness. In these models, the slip angle measures approximately $55^\circ$, the neck shaft angle is $115^\circ$, the femoral head diameter is 38 mm and the neck diameter is 18 mm.

Three groups were created; The first group (90°) was fixed perpendicular to the physis (n = 11, Synthes 6.5 mm cannulated screws, full threaded 75 mm #208.471), the second group (UEP) was fixed into the centre of the femoral head, oblique to the physis with its entry point from the anterior intertrochanteric ridge (n = 11, Synthes 6.5 mm cannulated screw fully threaded 55 mm #208.467) and the third group was a control, with no screw fixation, (n = 10) (Figs. 1 and 2). In a sacrificial sawbone, an ante-grade wire was placed in the centre of the femoral head to exit at the correct entry point. Once this was achieved, custom jigs were constructed so that the exact same path would be followed by retrograde guidewire placement. The custom jigs were used to reproducibly position a 1.8 mm guidewire retrograde into the correct position for each.

![Fig. 1](Images/1.jpg)

**Fig. 1** Photographs of the three groups of sawbones demonstrating screw path position perpendicular to the physis (90°), fixation into the centre of the femoral head from the Universal Entry Point (UEP), and an unfixed control (Control).
EFFECT OF SCREW POSITION IN SCFE

360

J Child Orthop 2020;14:358-363

Group, which was then overdrilled using a 5 mm cannulated drill and the screw inserted over the guidewire. The diaphysis of the femoral specimens was secured in a cylindrical testing jig and a shear force was applied across the proximal femoral physis on an Instron 5944 mechanical testing machine (Instron, Melbourne, Australia; Fig. 2). Loads were applied in displacement control at 0.5 mm/s to the endpoint of catastrophic failure. Primary outcomes tested were maximum load, stiffness and energy to failure.

Data analysis was performed using GraphPad Prism (Version 7; GraphPad Software, San Diego, California, USA). D’Agostino and Pearson normality tests confirmed normally distributed data, which was then analysed using one-way analysis of variance (ANOVA) followed by post-hoc Tukey’s for multiple comparisons.

Results

Due to the use of the custom jig, there were seven threads of the screw in the epiphysis in both test groups. Specimens with fixation into the centre of the femoral head, oblique to the physis, that utilized a UEP, withstood a statistically significantly higher maximum load than those with fixation perpendicular to the physis from an anterior starting point; 1047 ± 137.3 N (95% CI 954.5 – 1139 N) v 876.5 ± 132 N (787.8 - 965.2 N); p = 0.0132 (Fig. 3). The UEP Group absorbed statistically significantly greater energy prior to failure, (6.618 ± 2.333 J (5.051 - 8.186 J) v 4.559 ± 1.696 J (3.419 - 5.698 J); p = 0.0337). Fixation in UEP Group also provided a statistically significant stiffer construct (147.1 N/mm ± 9.387 (140.8 – 153.4)) compared to 90° Group (130.2 ± 13.54 N/mm (121.1 – 139.3), p = 0.0021). Both UEP and 90° Groups were significantly stronger than the controls; 536.2 +/- 122.5 N (448.5 - 623.8 N), both p < 0.0001. UEP and 90° Groups also absorbed significantly more energy than controls, 2.472 +/- 1.216 J (1.602 - 3.341 J), p = 0.0359 and < 0.0001, respectively. They also both exhibited significantly greater stiffness than the controls, 81.94 ± 7.625 N/mm (76.49 - 87.4); both p < 0.0001.

Fig. 2 Radiographs of the three groups of sawbones demonstrating screw path position perpendicular to the physis (90°), fixation into the centre of the femoral head from the Universal Entry Point (UEP), and an unfixed control (Control).
In 1980, Morrissey delivered an instructional course lecture in which he stated the ‘goal is to have the fixation device penetrate the centre of the epiphyseal plate at an angle perpendicular to it’. For mild SCFE this may be advantageous as it ensures the maximal number of threads across the physis. However, increasing slip severity requires an increasingly anterior starting point, which may result in an intracapsular entry point in soft metaphyseal bone, risk of loss of position and screw head impingement. Therefore, this surgical paradigm of screw fixation at 90° to the physis in all SCFE patients’ merits review.

To avoid these potential pitfalls, in situ pinning of chronic stable slips at the authors’ institution are performed by inserting a screw into the centre of the femoral head from the UEP. There are several potential benefits with this technique; by inserting the screw into the centre of the femoral head we can maximize the number of threads crossing the physis while minimizing the potential for pin penetration into the joint and subsequent cartilaginous injury. As demonstrated by Baumgartner and others, this significantly reduces the risk of cut out, which may confer similar benefits in SCFE. The UEP ensures good purchase of the proximal part of the fixation in the thickened cortical bone of the ridge, further reducing the risk of loss of position. This has the additional benefit of reducing the risk of fracture, which has been described with both anterior and lateral starting points. Thus, the UEP is named universal as it can be utilized in all in situ SCFE fixation. If in pre-operative planning a screw from the UEP will penetrate the posterior cortex, then a surgeon may wish to consider whether in situ fixation is appropriate. Although safer in the short term, placing the screw more...
proximally results in a weaker construct and results in an intraarticular screw head which may impinge.9

Our biomechanical model of a moderate SCFE demonstrated a statistically significant increase in maximum load, stiffness and energy to failure with screw fixation starting at the UEP and into the centre of the femoral head (oblique to the physis) compared with both screw fixation perpendicular to the physis and unfixed controls. We demonstrated a significant difference in energy to failure, with a 45% increase in energy to failure with those specimens fixed from the UEP compared to perpendicular fixation. We have previously shown energy to failure to be an important factor as deformity increases.22

Our study has some clear limitations; despite the homogeneity of our specimens, the synthetic femora may not accurately mimic human femora physiological behaviour seen in vivo. While replicating the clinical situation, UEP constructs had longer screws inserted (75mm versus 55mm) that may confer greater stability. In addition, we could not reproduce the normal curvature of the human physis in the sawbones where the silicone physis was produced across a straight cut.

Single screw fixation of SCFE into the centre of the femoral head from the UEP results in significantly increased maximum load, stiffness and energy to failure in this sawbone model. This approach may avoid the potential pitfalls associated with screw fixation perpendicular to the physis with its corresponding anterior starting point, of pin penetration, loss of fixation, impingement and fracture.

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COMPLIANCE WITH ETHICAL STANDARDS

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ETICAL STATEMENT
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AUTHOR CONTRIBUTIONS
JL: Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Drafting the work or revising it critically for important intellectual content; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
JAL: Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; Final approval of the version to be published; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
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