Basic Science

JOURNAL OF CHILDREN'S ORTHOPAEDICS

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

Jillian Lee[1,2]
Jonathon A. Lillia[2]
Jeremy M. Bellemore[1]
David G. Little[1,2,3]
Tegan L. Cheng[2,3]

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.

Cite this article: Lee J, Lillia JA, Bellemore JM, Little DG, Cheng TL. The Universal Entry Point with oblique screw is superior to fixation perpendicular to the physis in moderate slipped capital femoral epiphysis. *J Child Orthop* 2020;14:358-363. DOI: 10.1302/1863-2548.14.190178

Keywords: sawbone; SCFE; in situ fixation; Universal Entry Point

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

[1]Department of Orthopaedic Surgery, the Children's Hospital at Westmead, Sydney, NSW, Australia
[2]EPIC Lab, the Children's Hospital at Westmead, Sydney, NSW, Australia
[3]Department of Child and Adolescent Health, Sydney Medical School, University of Sydney, Sydney, NSW, Australia

Correspondence should be sent to Tegan Cheng, EPIC Lab, Kids Research, The Children's Hospital at Westmead, Locked Bag 4001, Westmead, NSW 2145, Australia.
E-mail: tegan.cheng@sydney.edu.au

provided adequate fixation with no screw related complications.[10] In a subsequent *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.[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.[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°, the neck shaft angle is 115°, 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 antegrade 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

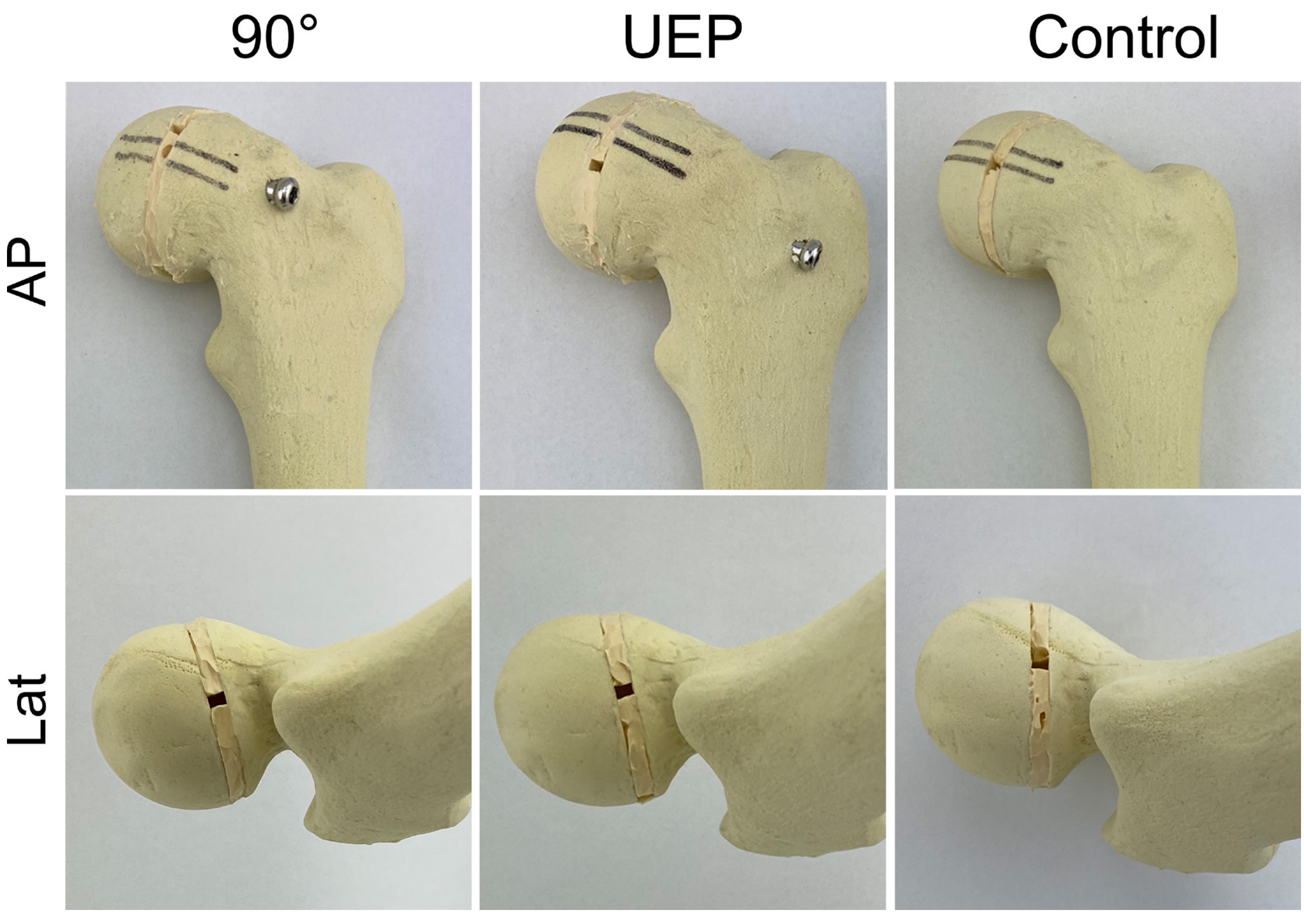

Fig. 1 Photographs of the three groups of sawbones demonstrating screw path position perpendicular to the physis (90°), fixation into the centre of the femoral head from the Universal Entry Point (UEP), and an unfixed control (Control).

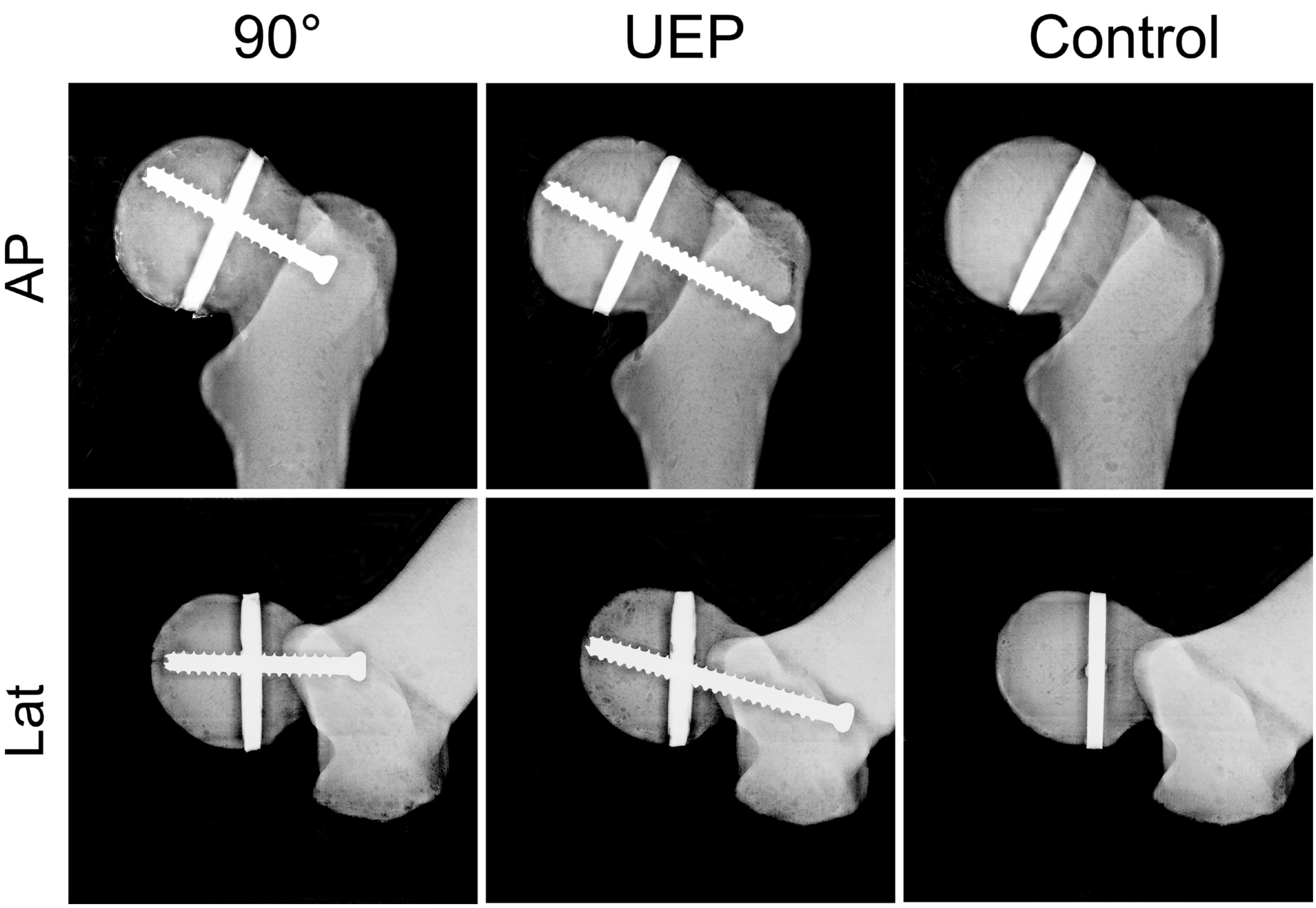

Fig. 2 Radiographs of the three groups of sawbones demonstrating screw path position perpendicular to the physis (90°), fixation into the centre of the femoral head from the Universal Entry Point (UEP), and an unfixed control (Control).

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.

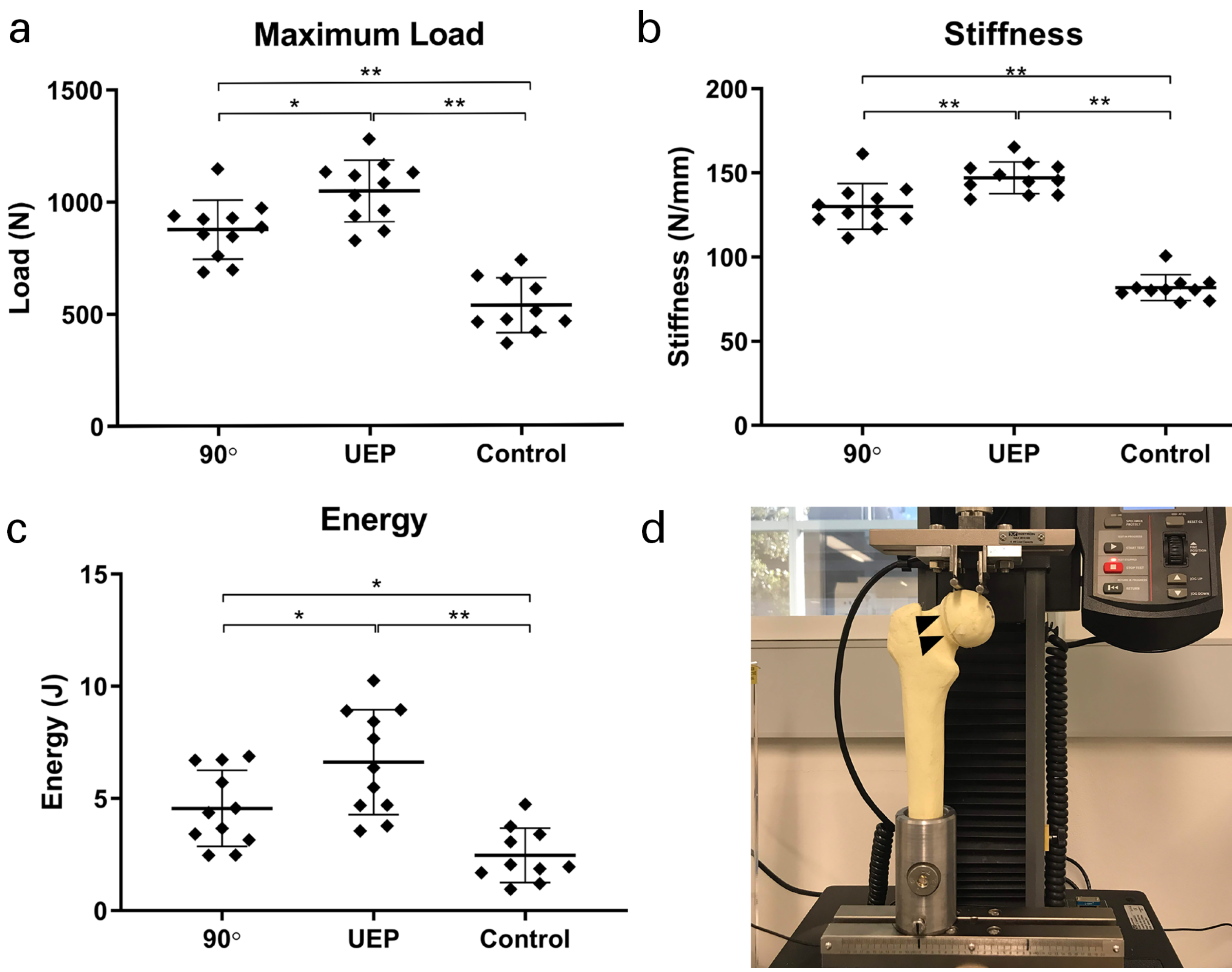

Fig. 3 The maximum load **(a)**, stiffness **(b)**, and energy absorbed **(c)** of a moderate SCFE sawbone loaded with a shear force through the simulated growth plate (*$p < 0.05$; **$p < 0.01$). The mechanical testing set up is shown in **(d)**, arrowheads indicate the location of the simulated physis.

Discussion

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'.[13] 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.[14] 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[15,16] while minimizing the potential for pin penetration into the joint and subsequent cartilaginous injury.[17] As demonstrated by Baumgartner and others, this significantly reduces the risk of cut out,[18] 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.[19-21] 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.

Received 25 November 2019; accepted after revision 24 July 2020

COMPLIANCE WITH ETHICAL STANDARDS

FUNDING STATEMENT

The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article.

ETHICAL STATEMENT

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent: Informed consent was not required for this work.

ICMJE CONFLICT OF INTEREST STATEMENT

DLG has received funding support from Novartis Pharma, Amgen Inc. UCB Pharma, Celgene, and N8 Medical for studies unrelated to this submission and is a consultant for Orthopediatrics.

All other authors declare no conflicts of interest.

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.

JMB: 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.

DGL: 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.

TLC: 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.

REFERENCES

1. **Novais EN, Millis MB.** Slipped capital femoral epiphysis: prevalence, pathogenesis, and natural history. *Clin Orthop Relat Res* 2012;470:3432-3438.

2. **Benson EC, Miller M, Bosch P, Szalay EA.** A new look at the incidence of slipped capital femoral epiphysis in new Mexico. *J Pediatr Orthop* 2008;28:529-533.

3. **Murray AW, Wilson NI.** Changing incidence of slipped capital femoral epiphysis: a relationship with obesity? *J Bone Joint Surg [Br]* 2008;90:92-94.

4. **Nguyen AR, Ling J, Gomes B, Antoniou G, Sutherland LM, Cundy PJ.** Slipped capital femoral epiphysis: rising rates with obesity and aboriginality in South Australia. *J Bone Joint Surg [Br]* 2011;93:1416-1423.

5. **Aronson DD, Carlson WE.** Slipped capital femoral epiphysis. A prospective study of fixation with a single screw. *J Bone Joint Surg [Am]* 1992;74:810-819.

6. **Ward WT, Stefko J, Wood KB, Stanitski CL.** Fixation with a single screw for slipped capital femoral epiphysis. *J Bone Joint Surg [Am]* 1992;74:799-809.

7. **Loder RT, Richards BS, Shapiro PS, Reznick LR, Aronson DD.** Acute slipped capital femoral epiphysis: the importance of physeal stability. *J Bone Joint Surg [Am]* 1993;75:1134-1140.

8. **Aronsson DD, Loder RT, Breur GJ, Weinstein SL.** Slipped capital femoral epiphysis: current concepts. *J Am Acad Orthop Surg* 2006;14:666-679.

9. **Goodwin RC, Mahar AT, Oswald TS, Wenger DR.** Screw head impingement after in situ fixation in moderate and severe slipped capital femoral epiphysis. *J Pediatr Orthop* 2007;27:319-325.

10. **Gourineni P.** Oblique in situ screw fixation of stable slipped capital femoral epiphysis. *J Pediatr Orthop* 2013;33:135-138.

11. **Merz MK, Amirouche F, Solitro GF, Silverstein JA, Surma T, Gourineni PV.** Biomechanical comparison of perpendicular versus oblique in situ screw fixation of slipped capital femoral epiphysis. *J Pediatr Orthop* 2015;35:816-820.

12. **Schmidt R, Gregg J.** Subtrochanteric fractures complicating pin fixation of slipped capital femoral epiphysis. *Orthop Trans* 1985;9:497.

13. **Morrissy RT.** Slipped capital femoral epiphysis: part II. Natural history and etiology in treatment. *American Academy of Orthopaedic Surgeons Instructional Course Lectures* 1980;XXIX:81-86.

14. **Hosalkar HS, Pandya NK, Bomar JD, Wenger DR.** Hip impingement in slipped capital femoral epiphysis: a changing perspective. *J Child Orthop* 2012;6:161-172.

15. **Carney BT, Birnbaum P, Minter C.** Slip progression after in situ single screw fixation for stable slipped capital femoral epiphysis. *J Pediatr Orthop* 2003;23:584-589.

16. **Upasani V, Kishan S, Oka R, et al.** Biomechanical analysis of single screw fixation for slipped capital femoral epiphysis: are more threads across the physis necessary for stability? *J Pediatr Orthop* 2006;26:474-478.

17. **Jofe MH, Lehman W, Ehrlich MG.** Chondrolysis following slipped capital femoral epiphysis. *J Pediatr Orthop B* 2004;13:29-31.

18. **Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM.** The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. *J Bone Joint Surg [Am]* 1995;77:1058-1064.

19. **Canale ST, Casillas M, Banta JV.** Displaced femoral neck fractures at the bone-screw interface after in situ fixation of slipped capital femoral epiphysis. *J Pediatr Orthop* 1997;17:212-215.

20. **Canale ST, Azar F, Young J, Beaty JH, Warner WC, Whitmer G.** Subtrochanteric fracture after fixation of slipped capital femoral epiphysis: a complication of unused drill holes. *J Pediatr Orthop* 1994;14:623-626.

21. **Baynham GC, Lucie RS, Cummings RJ.** Femoral neck fracture secondary to in situ pinning of slipped capital femoral epiphysis: a previously unreported complication. *J Pediatr Orthop* 1991;11:187-190.

22. **Bellemore JM, Carpenter EC, Yu NY, Birke O, Little DG.** Biomechanics of slipped capital femoral epiphysis: evaluation of the posterior sloping angle. *J Pediatr Orthop* 2016;36:651-655.