Journal of Hip Preservation Surgery, 2022, **9**, 90–94
DOI: https://doi.org/10.1093/jhps/hnac019
Advance access publication date: 9 April 2022
Research article

Is there a persistent capital femoral epiphysis growth after screw fixation for slipped capital femoral epiphysis?

Camille Sleth, François Bauzou, Claudia De Cristo, Fanny Alkar, Pauline Joly-Monrigal, Clément Jeandel, Jérôme Cottalorda, Djamel Louahem M'Sabah and Marion Delpont *

Pediatric Surgery, Lapeyronie Hospital, University of Montpellier, France.

*Correspondence to: M. Delpont. Department of Pediatric surgery, CHU Lapeyronie, 191 av du Doyen Gaston Giraud, Montpellier Cedex 5 34295, France. Tel: +0033 46733958; Fax: 0033 467330774. E-mail: m-delpont@chu-montpellier.fr

ABSTRACT

Femoral neck screwing during child development is controversial. The objective of this study was to evaluate the residual growth of the capital femoral physis after screw fixation. This retrospective study included children aged younger than 12 years treated for slipped capital femoral epiphysis (SCFE) with a single percutaneous partially threaded cannulated screw. The children were followed up for at least 1 year. Some patients also underwent prophylactic contralateral screwing. Preoperative, immediate postoperative and final follow-up X-rays were evaluated to determine the degree of slippage, pin–joint ratio (PJR), neck–pin ratio (NPR), number of threads crossing the physis, neck–shaft angle (NSA), screw–physis angle and screw position in the physis. We included 17 patients (29 hips: 18 SCFE and 11 prophylactic) with a mean age of 10.1 years (range: 7.1–11.9 years) at the time of surgery. Significant evolution of radiological growth parameters of the proximal femoral physis was noted during a mean follow-up of 2.4 years (range: 1–4.3 years). The mean PJR significantly decreased from 7.3 to 6.0, the mean NPR significantly decreased from 106 to 96 and the mean number of threads beyond the physis decreased from 3.3 to 1.8. The mean NSA decreased by 6.5°, from 139° to 132.5°. Persistent capital femoral epiphysis growth occurs after screw fixation. The NSA significantly decreases over time but remains within the physiological limits.

Level of evidence: IV (case series)

INTRODUCTION

Slipped capital femoral epiphysis (SCFE) is a paediatric hip disorder that has an incidence of 1–10 cases/100 000 people. SCFE impairs hip function due to potential long-term sequelae such as avascular necrosis, femoro-acetabular impingement and early osteoarthritis [1]. SCFE typically affects children aged 10–16 years. The average age of presentation in girls and boys is 12 and 13 years, respectively [2–4]. SCFE is bilateral in 20–80% of cases, and the second hip usually begins to slip within 1 year of the first [5]. Although the pathogenesis of SCFE is unclear, it is likely multifactorial and may involve mechanical and/or metabolic factors. Different studies have identified hormonal, biochemical or genetic factors at the origin of skeletal maturation disorders that can promote SCFE [6, 7]. An age-related change in the shape of the femoral growth plate, from pleated to spherical, may explain why SCFE affects most of the time children aged >10 years [8]. Additionally, SCFE can be associated with obesity or an abnormal hip morphology (increased physeal obliquity, relative retroversion or coxa profunda) [9–11].

The ideal fixation device for SCFE treatment should prevent further slippage and allow residual growth. *In situ* fixation with a single cannulated screw in the centre of the epiphysis is effective for slowing SCFE progression. This has become the most widely accepted treatment for mild and moderate SCFE cases even if some chondrolysis may still occur if the screw penetrates the articular surface of the femoral head [12–14]. Because the screw crosses the physis, some degree of growth arrest of the proximal femoral physis is expected after percutaneous screw fixation. However, the extent of growth arrest is still unclear [15–17]. Consequently, in young patients, some authors recommend pinning fixation with smooth pins. However, pinning fixation is associated with severe complications such as secondary displacement and chondrolysis [1, 18, 19].

The main objective of this study was to know if there was a persistent growth of proximal femoral physis after fixation of SCFE with a single cannulated screw in children and adolescents with remaining growth. A secondary objective was to study the variation in the neck–shaft angle (NSA) after fixation of SCFE.

Submitted 15 September 2021; Revised 3 March 2022; revised version accepted 10 March 2022

MATERIALS AND METHODS

This single-centre retrospective study included children with SCFE, who were aged 12 years or below at the time of treatment with a single cannulated screw between 2000 and 2019 and were followed up for at least 1 year. We also included hips prophylactically treated with a single cannulated screw. We excluded children if they were aged above 12 years at the time of surgery, had incomplete documentation or were treated with osteotomy, K-wires or other types of treatment. The protocol followed the guidelines of the Helsinki Convention. Written informed consent was obtained from the children and their legal representatives.

We reviewed the medical and radiological reports and collected data on age, sex, laterality, follow-up, contralateral screwing, complications and surgery revision. Hips were also classified according to the Loder Classification [4]: unstable SCFEs were those that caused severe pain that made walking impossible even with crutches. Slips were considered to be stable when the patient could bear weight, with or without crutches.

Surgery was performed on an orthopaedic table with the patient in the supine position. A distally threaded, percutaneous, cannulated 6.5 inox screw was inserted into the femoral neck under fluoroscopic guidance. Two C-arms were simultaneously used: one was positioned for the anteroposterior view and the other for the lateral view. Postoperatively, weightbearing was not allowed for 6 weeks.

Anteroposterior and frog leg lateral view radiographs, obtained immediately after surgery and at the last follow-up, were analysed to determine the Risser stage, SCFE angle and type, according to the Southwick Slip Angle Classification [20], number of threads crossing the physis, time to physeal fusion, NSA and screw–physis angle (angle between the long axis of the screw and growth plate). The screw position was recorded as being in the upper, central or lower third of the epiphysis. Residual growth was assessed on frontal X-ray images obtained immediately after surgery and at the last follow-up, according to the method described by Laplaza and Burke [15]. The pin–joint ratio (PJR) was calculated as the distance from the screw tip to the joint in relation to the screw length. The neck–pin ratio (NPR) was calculated as the distance (in line with the screw) between the joint and physis divided by the screw length (Fig. 1). All measurements were performed by a single senior paediatric surgeon to limit variations in radiological measurements. A difference of >5% in the PJR or NPR between the immediately postoperative and last follow-up radiographs was considered to indicate persistent growth.

Variations in radiographic measurements were analysed using the Wilcoxon signed-rank test. Pearson's correlation analysis was used to identify correlations of NSA with age at the time of surgery and screw–physis angle. Statistical analysis was performed using SPSS software (version 13.0; IBM Corp., Armonk, NY, USA). Statistical significance was defined as $P < 0.05$.

RESULTS

This study included 17 patients (11 females and 6 males) and 29 hips (15 left and 14 right; 18 with SCFE and 11 with prophylactic surgery). The surgery was performed by five senior surgeons. The average age at surgery was 10.1 years (range: 7.1–11.9 years).

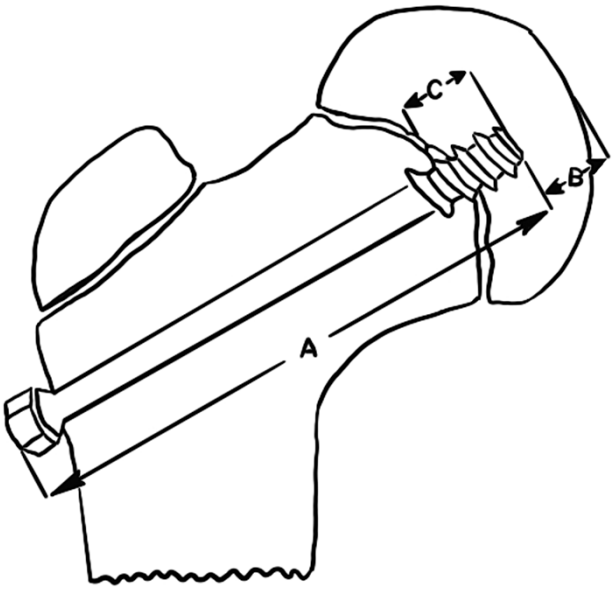

Fig. 1. Assessment of femoral neck growth after screw fixation: pin–joint ratio = B/A × 100; neck–pin ratio: (B + C)/A × 100. A = length of the screw, B = length between the end of the screw and the articulation, C = length of the screw after the physis.

Table I. Evolution of radiological parameters

	Immediate post-operative	*Last follow-up*	*P*
Pin–joint ratio	6 (3.2–13.8)	7.3 (5–18.1)	0.00125
Neck–pin ratio	106 (104.1–109.4)	110 (104.7–119)	0.000008
Number of threads	3.3 (2–4)	1.8 (0–4)	0.0011
Neck–shaft angle	139° (124–148°)	132° (123–141°)	0.00295

Fifteen patients (88.2%) had a Risser stage of 0, while 2 (11.7%) had a Risser stage of 1. The average degree of slippage was 34° (range: 10–80°). Nineteen, seven and three hips were stages 1–3, respectively. Twenty-four hips were stable, four previously stable hips were unstable and one was unstable. Four unstable hips underwent preoperative gentle closed reduction under general anaesthesia without any traction when the patient was placed on the orthopaedic table, before screw fixation.

The mean follow-up duration was 2.4 years (range: 1–4.3 years). The number of threads crossing the growth plate on X-rays decreased from 3.3 (range 2–4) to 1.8 (range 0–4) from the immediate postoperative period to the last follow-up ($P = 0.0011$) (Table I). All hips demonstrated growth, with an increase of >5% in the PJR and NPR. Physeal growth (PJR and NPR) significantly varied among the hips (Table I). The NSA significantly decreased in all hips ($P = 0.00295$), from an average of 139° (range: 124–148°) at the time of surgery to 132.5° (range: 123–141°) at the last follow-up.

NSA did not significantly correlate with the age at the time of surgery or screw–physis angle at the last follow-up. The mean interval from hip fixation to proximal femoral physeal closure was

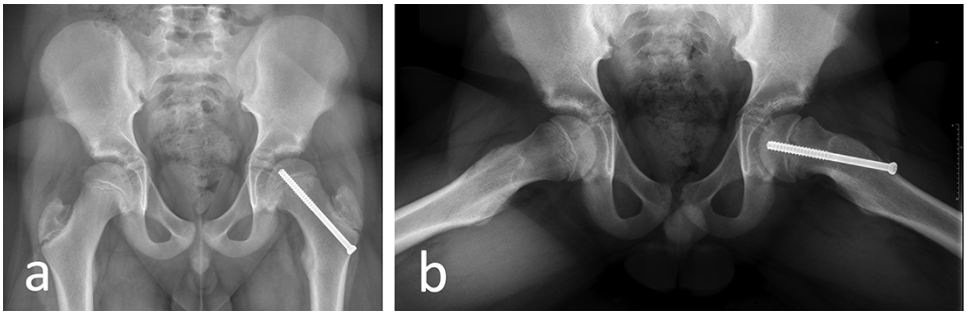

Fig. 2. Radiological result of an 11-year-old boy treated for unstable SCFE of the left hip with a cannulated screw. (a) Anteroposterior radiograph obtained immediately after surgery. (b) Frog leg lateral view radiograph obtained immediately after surgery.

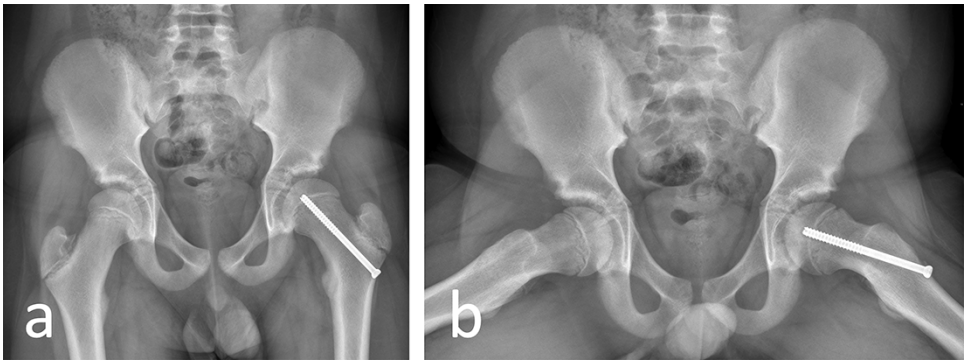

Fig. 3. Radiological result of the patient shown in Fig. 2 2 years later, just before revision surgery for epiphysis 'growing off' the screw. (a) Anteroposterior radiograph. (b) Frog leg lateral view radiograph.

25.4 months (range: 0.5–48 months). The screw was placed in the central, lower and upper third of the epiphysis in 26 (90%), 2 (7%) and 1 (3%) hips out of 29 hips, respectively. Five patients underwent hardware removal after physeal closure because at the beginning of our work, we removed the screw at the end of growth. The procedural complications included two cases of failure of hardware removal. Two patients underwent replacement of the screw due to the epiphysis 'growing off' the screw (Figs 2 and 3). No cases of chondrolysis, avascular necrosis or slippage progression were observed.

DISCUSSION

SCFE patients aged younger than 12 years and those with prophylactic fixation of the femoral neck experience persistent capital femoral epiphysis growth after screw fixation. Capital femoral fixation with a cannulated screw is the gold standard treatment for mild and moderate SCFE [21–24]. Some studies reported persistent growth after screw fixation, but these included a small sample or patients undergoing prophylactic fixation [15–17, 21–24]. Breaud et al. demonstrated persistent growth in 12 of 13 hips fixed with a fully threaded cannulated screw [17]. Vlachopoulos et al. observed persistent epiphyseal growth in 10 of 11 patients treated with prophylactic fixation using a partially threaded single cannulated screw. Based on that study, it was concluded that prophylactic fixation may not be feasible for premature closure of the physis to minimize leg length discrepancy, and screw fixation should only be considered to support the physis during growth [16]. Persistent growth may be explained on the basis of the structure of the growth plate of the proximal femoral epiphysis. The growth plate consists of two parts: a discoid part within the metaphysis and a spherical part at the edge of the head, which involves circumferential growth of cartilage below the articular cartilage. In the femoral head, growth occurs in a centripetal manner 'around' the screw [25], which causes 'growing off' of the epiphysis from the screw in some patients.

Conversely, Laplaza et al. reported that a single central cannulated screw caused physeal closure 6.3 months after surgery. However, the patients in their study were older compared to those in our study [15]. Importantly, pinning instead of screwing does not prevent growth of the femoral neck. Segal et al. observed abnormal growth of the proximal femur after pinning fixation in young children treated for SCFE, particularly coxa vara and coxa brevis caused by premature proximal physeal arrest [18]. Secondary displacement and loss of efficiency of the pins due to growth in some patients may explain these growth disorders.

In our study, the NSA angle decreased but remained within the physiological limits. Slight variation in angle of the proximal femur after screwing has previously been described and is even useful for the treatment of coxa valga [26, 27]. To induce significant variation in the angle, screwing has to be performed in patients aged younger than 5 years, which is much younger than SCFE patients. Additionally, the transphyseal screw has to be placed in the inferomedial part of the physis to create a varus. In 90% of our patients, the screw was placed in the central third of the epiphysis. Despite this, we noticed greater progression in the varus of two hips with screws in the lower third

of the epiphysis. To prevent coxa vara after SCFE, it is essential to avoid the inferomedial screw position. The screw should be placed in the most central position, as perpendicular to the physis as possible. Another explanation for the low incidence of growth disorders in our study may be that the surgeons have been performing osteotomy in patients with stable SCFE and slippage >45° for over 10 years. Some patients with severe disease were excluded from the study. The correct placement of the percutaneous screw in the femoral neck is easier in patients with moderate or non-displaced SCFE. A slight anatomical variation of the femoral neck also occurs during normal growth. Proximal femur growth is affected by growth plate geometry and the action of mechanical forces [28]. Gait loading during growth physiologically reduces the NSA [28, 29]. The NSA decreases during development, from about 150° to 125° [30]. More precisely, it decreases sharply during the first years of life, from 150° at 1 year, then 145° at 5 years and 135° at 10 years. It then decreases more slowly to ∼130° at 16 years [31]. Although it would be useful to compare growth between SCFE and contralateral hips, it was previously recommended that the contralateral hip be prophylactically fixed [32]. Currently, prophylactic contralateral fixation is recommended only for patients with endocrine or systemic disorders because of complications after femoral neck screwing [33–36]. In our study, only five hips did not have contralateral prophylactic surgery. In these patients, the NSA did not differ significantly between the operated and non-operated hips at the last follow-up, but this involved too few patients to conclude.

Other methods of percutaneous fixation can also be used. Upasani et al. studied partially threaded screws and reported that *in vitro* use of 16-mm thread screws was associated with adequate strength and stiffness if 40–60% of the threads were engaged in the epiphysis [24]. Dragoni et al. reported that 16-mm threaded screws had the highest rate of neck failure [21]. More than five threads should be engaging the epiphysis to prevent slip progression and epiphyses 'growing off' from the screw [37]. Unfortunately, it is often difficult to obtain more than three threads without using a very long screw, especially in young children [16, 37]. Nevertheless, we did not observe any cases of slip progression in our study, despite several cases of epiphysis 'growing off' the screw. This may be explained by close monitoring of the hips, especially in younger patients, and prompt replacement of the screw if required. Careful follow-up is essential because the number of threads crossing the growth plate decreases over time, which poses a risk of mechanical instability and femoral epiphysis slippage. Although partially threaded screws may be difficult to remove, screw removal is increasingly discouraged in SCFE patients [38, 39]. The indication of the removal of the screw has evolved over time and remains controversial. At the beginning of our work, we removed the screw at the end of growth. After the report of recurrence of SCFE after screw removal or complications due to the difficulty of removing the screw have been described, we no longer remove the screws unless there is pain due to the screw. An alternative may be to use fully threaded screws; however, they are associated with less compression in cases of instability. Some surgeons use 'inverse threaded' or 'free-gliding' screws to prevent growth disorders [40]. We do not recommend the use of pins because of the risk of complications due to secondary displacement.

This study had some limitations. Although the sample size was small, it included a greater number of patients compared to previous studies. Epiphysiolysis is a rare condition, which mostly affects patients younger than 12 years. This was a retrospective study. However, SCFE is an uncommon condition, and it would have taken several years to recruit a large number of patients. Besides, the follow-up is limited. Although the results are encouraging, it would be interesting to repeat this work once all the patients have reached skeletal maturity and a longer follow-up. We did not evaluate other radiological or clinical factors because the purpose of this study was to assess residual neck growth after screwing. Also, we did not use other imaging modalities, such as computed tomography, because they are not part of the routine workup during follow-up of these patients and computed tomography scans are associated with radiation exposure.

CONCLUSION

Significant and persistent growth of proximal femoral epiphysis occurs in patients younger than 12 years with SCFE treated with a single central cannulated screw. The NSA significantly varied in patients with varus but did not exceed the normal values according to patients' age.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author (M.D.) upon reasonable request.

ACKNOWLEDGEMENTS

None.

FUNDING

This study had no financial support.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Millis MB, Novais EN. In situ fixation for slipped capital femoral epiphysis: perspectives in 2011. *J Bone Joint Surg* 2011; **93**: 46–51.
2. Zaltz I, Baca G, Clohisy JC. Unstable SCFE: review of treatment modalities and prevalence of osteonecrosis. *Clin Orthop Relat Res* 2013; **471**: 2192–8.
3. Larson AN, Sierra RJ, Yu EM *et al.* Outcomes of slipped capital femoral epiphysis treated with in situ pinning. *J Pediatr Orthop* 2012; **32**: 125–30.
4. Loder RT, Richards BS, Shapiro PS *et al.* Acute slipped capital femoral epiphysis: the importance of physeal stability. *J Bone Joint Surg Am* 1993; **75**: 1134–40.
5. Loder RT, Aronson DD, Greenfield ML. The epidemiology of bilateral slipped capital femoral epiphysis. a study of children in Michigan. *J Bone Joint Surg Am* 1993; **75**: 1141–7.
6. Serrano-Gonzalez M, Shay S, Austin J *et al.* A germline mutation of HRPT2/CDC73 (70 G>T) in an adolescent female with parathyroid carcinoma: first case report and a review of the literature. *J Pediatr Endocrinol Metab* 2016; **29**: 1005–12.
7. Ko JM, Bae J-S, Choi JS *et al.* Skeletal overgrowth syndrome caused by overexpression of C-type natriuretic peptide in a girl with balanced chromosomal translocation, t(1;2)(q41;q37.1). *Am J Med Genet A* 2015; **167A**: 1033–8.

8. Kandzierski G, Matuszewski Ł, Wójcik A. Shape of growth plate of proximal femur in children and its significance in the aetiology of slipped capital femoral epiphysis. *Int Orthop* 2012; **36**: 2513–20.
9. Weiner D. Pathogenesis of slipped capital femoral epiphysis: current concepts. *J Pediatr Orthop B* 1996; **5**: 67–73.
10. Novais EN, Millis MB. Slipped capital femoral epiphysis: prevalence, pathogenesis, and natural history. *Clin Orthop Relat Res* 2012; **470**: 3432–8.
11. Bhatia NN, Pirpiris M, Otsuka NY. Body mass index in patients with slipped capital femoral epiphysis. *J Pediatr Orthop* 2006; **26**: 197–9.
12. Naseem H, Chatterji S, Tsang K *et al.* Treatment of stable slipped capital femoral epiphysis: systematic review and exploratory patient level analysis. *J Orthop Traumatol* 2017; **18**: 379–94.
13. Abu Amara S, Leroux J, Lechevallier J. Surgery for slipped capital femoral epiphysis in adolescents. *Orthop Traumatol Surg Res* 2014; **100**: S157–67.
14. Nectoux E, Décaudain J, Accadbled F *et al.* Evolution of slipped capital femoral epiphysis after in situ screw fixation at a mean 11 years' follow-up: a 222 case series. *Orthop Traumatol Surg Res* 2015; **101**: 51–4.
15. Laplaza FJ, Burke SW. Epiphyseal growth after pinning of slipped capital femoral epiphysis. *J Pediatr Orthop* 1995; **15**: 357–61.
16. Vlachopoulos L, Huber H, Dierauer S *et al.* Persisting growth after prophylactic single-screw epiphysiodesis in upper femoral epiphysis. *J Pediatr Orthop* 2013; **33**: 816–20.
17. Breaud J, Rubio A, Leroux J *et al.* Residual hip growth after pinning of slipped capital femoral epiphysis. *J Pediatr Orthop B* 2009; **18**: 7–9.
18. Segal LS, Davidson RS, Robertson JW *et al.* Growth disturbances of the proximal femur after pinning of juvenile slipped capital femoral epiphysis. *J Pediatr Orthop* 1991; **11**: 631–7.
19. Millis MB. SCFE: clinical aspects, diagnosis, and classification. *J Child Orthop* 2017; **11**: 93–8.
20. Southwick WO. Osteotomy through the lesser trochanter for slipped capital femoral epiphysis. *J Bone Joint Surg* 1967; **49**: 807–35.
21. Dragoni M, Heiner AD, Costa S *et al.* Biomechanical study of 16-mm threaded, 32-mm threaded, and fully threaded SCFE screw fixation. *J Pediatr Orthop* 2012; **32**: 70–4.
22. Miyanji F, Mahar A, Oka R *et al.* Biomechanical comparison of fully and partially threaded screws for fixation of slipped capital femoral epiphysis. *J Pediatr Orthop* 2008; **28**: 49–52.
23. Early SD, Hedman TP, Reynolds RA. Biomechanical analysis of compression screw fixation versus standard in situ pinning in slipped capital femoral epiphysis. *J Pediatr Orthop* 2001; **21**: 183–8.
24. 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**: 474–8.
25. Lagrange J, Dunoyer J. The vascularization of the femur head in children. *Rev Chir Orthop* 1962; **48**: 123–37.
26. Torode IP, Young JL. Caput valgum associated with developmental dysplasia of the hip: management by transphyseal screw fixation. *J Child Orthop* 2015; **9**: 371–9.
27. Portinaro N, Turati M, Cometto M *et al.* Guided growth of the proximal femur for the management of hip dysplasia in children with cerebral palsy. *J Pediatr Orthop* 2019; **38**: e622–8.
28. Yadav P, Shefelbine SJ, Gutierrez-Farewik EM. Effect of growth plate geometry and growth direction on prediction of proximal femoral morphology. *J Biomech* 2016; **49**: 1613–9.
29. Tamari K, Tinley P, Briffa K *et al.* Validity and reliability of existing and modified clinical methods of measuring femoral and tibiofibular torsion in healthy subjects: use of different reference axes may improve reliability. *Clin Anat* 2005; **18**: 46–55.
30. Isaac B, Vettivel S, Prasad R *et al.* Prediction of the femoral neck-shaft angle from the length of the femoral neck. *Clin Anat* 1997; **10**: 318–23.
31. Birkenmaier C, Jorysz G, Jansson V *et al.* Normal development of the hip: a geometrical analysis based on planimetric radiography. *J Pediatr Orthop B* 2010; **19**: 1–8.
32. Puylaert D, Dimeglio A, Bentahar T. Staging puberty in slipped capital femoral epiphysis: importance of the triradiate cartilage. *J Pediatr Orthop* 2004; **24**: 144–7.
33. Abu Amara S, Cunin V, Ilharreborde B. Severe slipped capital femoral epiphysis: a French multicenter study of 186 cases performed by the SoFOP. *Orthop Traumatol Surg Res* 2015; **101**: S275–9.
34. Loder RT, Wittenberg B, DeSilva G. Slipped capital femoral epiphysis associated with endocrine disorders. *J Pediatr Orthop* 1995; **15**: 349–56.
35. Sankar WN, Novais EN, Lee C *et al.* What are the risks of prophylactic pinning to prevent contralateral slipped capital femoral epiphysis? *Clin Orthop Relat Res* 2013; **471**: 2118–23.
36. Castro FP, Bennett JT, Doulens K. Epidemiological perspective on prophylactic pinning in patients with unilateral slipped capital femoral epiphysis. *J Pediatr Orthop* 2000; **20**: 745–8.
37. 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**: 584–9.
38. Raney EM, Freccero DM, Dolan LA *et al.* Evidence-based analysis of removal of orthopaedic implants in the pediatric population. *J Pediatr Orthop* 2008; **28**: 701–4.
39. Herngren B, Stenmarker M, Enskär K *et al.* Outcomes after slipped capital femoral epiphysis: a population-based study with three-year follow-up. *J Child Orthop* 2018; **12**: 434–43.
40. Morash K, Orlik B, El-Hawary R *et al.* Femoral neck growth and remodeling with free-gliding screw fixation of slipped capital femoral epiphysis. *J Pediatr Orthop* 2021; **41**: e309–15.