Cam deformity and hip degeneration are common after fixation of a slipped capital femoral epiphysis

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Background and purpose — Slipped capital femoral epiphysis is thought to result in cam deformity and femoroacetabular impingement. We examined: (1) cam-type deformity, (2) labral degeneration, chondrolabral damage, and osteoarthritic development, and (3) the clinical and patient-reported outcome after fixation of slipped capital femoral epiphysis (SCFE).

Methods — We identified 28 patients who were treated with fixation of SCFE from 1991 to 1998. 17 patients with 24 affected hips were willing to participate and were evaluated 10–17 years postoperatively. Median age at surgery was 12 (10–14) years. Clinical examination, WOMAC, SF-36 measuring physical and mental function, a structured interview, radiography, and MRI examination were conducted at follow-up.

Results — Median preoperative Southwick angle was 22o (IQR: 12–27). Follow-up radiographs showed cam deformity in 14 of the 24 affected hips and a Tönnis grade > 1 in 1 affected hip. MRI showed pathological alpha angles in 15 affected hips, labral degeneration in 13, and chondrolabral damage in 4. Median SF-36 physical score was 54 (IQR: 49–56) and median mental score was 56 (IQR: 54–58). These scores were comparable to those of a Danish population-based cohort of similar age and sex distribution. Median WOMAC score was 100 (IQR: 84–100).

Interpretation — In 17 patients (24 affected hips), we found signs of cam deformity in 18 hips and early stages of joint degeneration in 10 hips. Our observations support the emerging consensus that SCFE is a precursor of cam deformity, FAI, and joint degeneration. Neither clinical examination nor SF-36 or WOMAC scores indicated physical compromise.

In femoroacetabular impingement (FAI), repeated trauma to the acetabular labrum and adjacent chondral structures may result in labral degeneration, tearing of the labrum, chondral delamination, and osteoarthritis development. Cam-type deformity is characterized by loss of sphericity of the femoral head and decreased head/neck offset laterally and anteriorly (Figure 1A). This deformity has been identified in 17–24% of men and in 4% of women (Gosvig et al. 2008, Reichenbach et al. 2010) and is believed to be one of the main contributors to osteoarthritic development. The etiology of cam-type deformity remains unclear (Beck et al. 2005, Ganz et al. 2008, Jessel et al. 2009, Leunig et al. 2009, Barros et al. 2010, Klit et al. 2011), high intensity of sports activity during adolescence has been associated with increased risk of cam-type deformity (Siebenrock et al. 2011).

Slipped capital femoral epiphysis (SCFE) is thought to be a precursor of cam-type deformity and therefore possibly also development of osteoarthritis (Murray 1965, Stulberg et al. 1975, Harris 1986, Leunig et al. 2000, 2009, Beck et al. 2005, Ganz et al. 2008, Gosvig et al. 2008b, Murray and Wilson 2008, Mamisch et al. 2009, Barros et al. 2010, Klit et al. 2011). In typical SCFE (Figure 1B), the epiphysis stays in the acetabular socket and the femoral metaphysis is displaced anteriorly and superiorly, creating the impression of an epiphysis that has slipped posteriorly and inferiorly. The consequence is a reduced or complete loss of head/neck offset, which resembles a prototype of cam-type deformity (Harris 1986, Mintz et al. 2005, Lehmann et al. 2006, Jessel et al. 2009).

SCFE is the most common hip disorder in adolescence (Lehmann et al. 2006, Gholve et al. 2009) with a prevalence of asymptomatic so-called silent SCFE of 3% in girls and 10% in boys (Lehmann 2008, personal communication), which is less than the population-based prevalence estimates of cam-type deformity in adults of 4–24% (Lehmann 2008, Gosvig et al. 2010, Reichenbach et al. 2010) .

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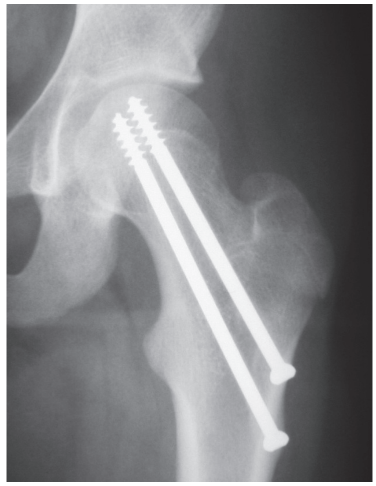

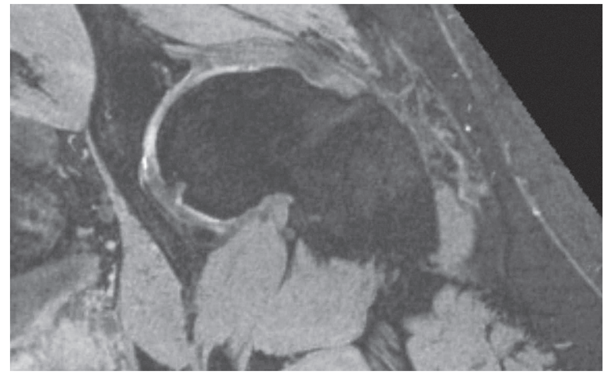

Figure 1. A. CAM-type deformity with characteristic loss of sphericity of the femoral head and decreased head/neck offset laterally and anteriorly after SCFE with in situ screw fixation.

B. SCFE with loss of sphericity of the femoral head and decreased head/neck offset laterally and anteriorly and in situ screw fixation.

C. Radial reconstruction of a MRI 3T scan showing anterior CAM-type deformity with the characteristic loss of sphericity of the femoral head and decreased head/neck offset anteriorly at 15 years after SCFE with in situ screw fixation.

To test the hypothesis that SCFE results in cam-type deformity, we raised the following questions: (1) does cam-type deformity or (2) do labral degeneration, chondrolabral damage, and osteoarthritic development appear at 10–17 years of follow-up after fixation of SCFE; and (3) is the clinical and patient-reported outcome affected?

Patients and methods (Figure 2)

We searched databases at Aarhus University Hospital and Hvidovre University Hospital and identified 28 patients who had had in situ fixation of SCFE between 1991 and 1998 and had not been converted to a total hip arthroplasty. 17 patients (10 women) with 24 affected hips were willing to participate in this ethics committee-approved study (no. M-20080062).

Of the 17 participating patients, 10 had unilateral SCFE and 7 had bilateral SCFE. 3 patients with unilateral SCFE had prophylactic simultaneous contralateral pinning performed. Based on Southwick's definitions (Southwick 1967), we identified 18 hips with a chronic slip, 2 with acute-on-chronic, 2 with acute slip (pain < 3 weeks), and 2 others whose level of chronicity could not be specified. Median age at surgery was 12 (10–14) years. 1 patient had subsequent proximal femoral valgus osteotomy performed. The patients were evaluated in 2008 with a mean follow-up of 15 (10–17) years. The 11 patients (3 women) who declined to participate in the follow-up had a median age at surgery of 12 (10–13) years.

Hips were operated on with insertion of 1 or 2 screws through a minimal skin incision. The aim was central placement of the screw in the femoral head in both radiographic planes. Patients had postoperative radiographs taken. In many cases they were followed for 1 year postoperatively and in some cases they were followed until radiographic closure of the physis. Radiographic examinations consisted of 2 views, most often AP and Lauenstein views.

All clinical examinations were performed by 2 of the authors: AT in Aarhus and KG in Hvidovre. Follow-up

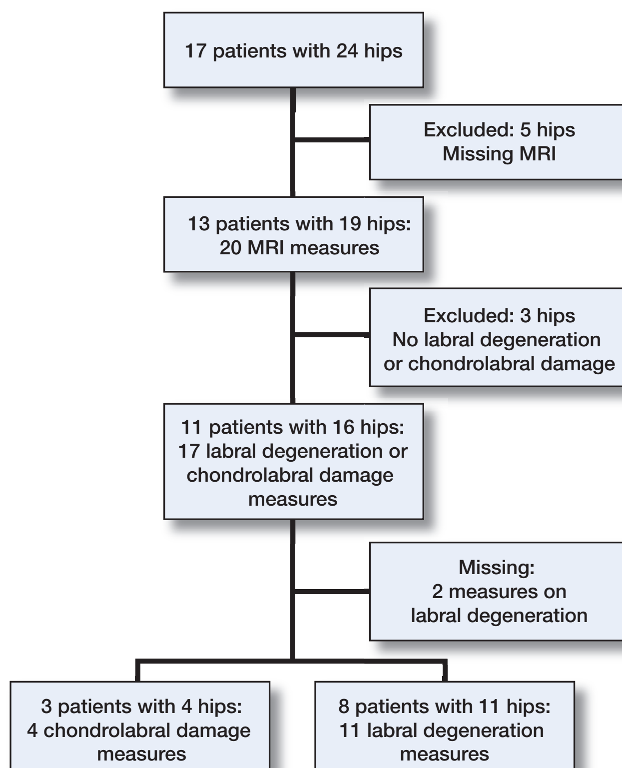

Figure 2. Flow diagram for obtainment of measures of labral degeneration and chondrolabral damage in affected hips.

included clinical examination, WOMAC and SF-36 questionnaires, conventional radiography (AP pelvic and Lauenstein views), and MRI. Clinical examination included ROM and the impingement test. The impingement test was performed by internally rotating and adducting the 90o-flexed hip and they were considered positive if groin pain resulted (Troelsen et al. 2009). At follow-up, health-related quality of life (HRQoL) was assessed using the SF-36 version 1 questionnaire. Data are presented as physical and mental component scores and are compared with normative data for a cohort of similar age from the Danish population (Bjørner et al. 1997). To assess hip-specific patient-reported outcome, we used the WOMAC questionnaire (Bellamy et al. 2011). Data were transformed to a scale from 0 to 100 (100 being the best possible score), taking into account differences in scale length.

MRI was performed at both hospitals. Hips with retained metal implants (n = 3) were excluded from MRI evaluation as a result of metal artifacts distorting the area close to the implant. All other hips were included and found to be suitable for evaluation, including the opposite hip to those with retained implants. At Aarhus University Hospital, MRI was performed using a Philips 3-T scanner (Best, the Netherlands). Proton density-weighted SPAIR sequences in the sagittal, coronal, and axial planes were obtained followed by a coronal T1 sequence and a T2-weighted 3-D sequence with fat suppression. At Hvidovre University Hospital, all MRIs were performed using a Siemens Trio 3-T scanner (Erlangen, Germany) (Figure 1C). Proton density-weighted fat-saturated turbo spin echo sequences in the coronal, axial, and sagittal planes were obtained, followed by a unique Dess 3-D sequence. Radial reconstructions were obtained from the 3-D sequences around the axis of the femoral neck. Cam malformations were assessed by the alpha angle, as described by Nötzli et al. (2002). Labral degeneration was defined by irregular margins and intermediate signal intensity. Chondrolabral damage was identified by a linear band of high signal intensity, detected in the labrum or at the chondrolabral transition zone. Based on the primary localization of labral degeneration or chondrolabral damage, each condition was assigned to 1 of 4 acetabular quadrants: anteroinferior, anterosuperior, posterosuperior, or posteroinferior (Troelsen et al. 2007). Although 1.5-T MRI arthrography has been the gold standard in evaluating labral changes and chondral changes, non-contrast conventional MRI has been valid in detecting structural labral changes (Mintz et al. 2005, Robinson 2012). All MRIs were assessed by 2 of the authors (EM and KG) as consensus readings; the first is a senior consultant in radiology specialized in orthopedic MRI and the latter is a radiologist with 3 years of experience.

All preoperative radiographs were digitized and—together with follow-up radiographs—examined using Synedra software (Synedra View Personal Version 3; Synedra Information Technologies GmbH, Innsbruck, Austria). All radiographs were assessed by one author (JK). To describe the severity of the SCFE, the Southwick angle was measured on the preoperative radiographs in the frog-leg lateral view (Southwick 1967, 1984). A Southwick angle in the interval 30° to 50° was considered a moderate slip (Southwick 1967, Loder et al. 2006). In 8 of 24 hips, measurements of the Southwick angle could not be made because only preoperative AP views were available. The median preoperative Southwick angle was 22° (12–27). The triangular index described by Gosvig et al. (2007) was used to assess whether cam deformity was present at follow-up. An index of > 2 describes definite cam-type deformity. Osteoarthritic changes were assessed according to the Tönnis classification (Tönnis 1976). We have previously reported intra- and interobserver variance measures of the Tönnis classification and the triangular index (Gosvig et al. 2007, Troelsen et al. 2010).

Statistics

Descriptive statistics were performed on all variables of interest. Categorical variables were displayed with crude number (rate), and, if not otherwise stated, data are presented as continuous variables with median and interquartile range (first and third quartile). We assumed dependency in the hips of the same patient. Since some patients had 2 affected hips, empirical 95% bootstrap confidence intervals (CIs) were calculated for all variables to show their accuracy (Efron et al. 1996). These CIs are based on bootstraps with 10,000 samplings with replacement at the patient level. Extension, flexion, internal rotation, and external rotation were tested for differences between the affected hips and the unaffected hips. Again, because of the within-patient hip dependency, a bootstrap hypothesis test was preformed with 10,000 permutations at the patient level and we used the t-test to calculate the test statistic. If not otherwise stated, data are presented as median with interquartile range. Data were analyzed using R version 3.0.2 (R Foundation for Statistical Computing, Vienna, Austria).

SF-36 data were processed using the software supplied for the SPSS package.

Results

On conventional radiographs at the last follow-up, the triangular index was pathological (> 2) in 14 of 22 affected hips (rate = 0.3, 95% CI: 0.4–0.9), indicative of cam-type deformity. In 15 of 17 affected hips (88%, CI: 65–100) evaluated by MRI at follow-up, the alpha angle of Nötzli et al. was > 55°, representing a pathological angle indicative of cam-type deformity. The median alpha angle was 83° (IQR: 62–95; CI: 62–95).

1 of 22 affected hips (0.05, CI: 0–0.1) had osteoarthritis, corresponding to a Tönnis grade of > 1 on conventional radiography.

MRI showed labral degeneration in 13 of 19 (rate = 0.7, CI: 0.4–0.9) affected hips and chondrolabral damage in 4 of 19

Table 1. ROM for affected and unaffected hips

Variable	Affected hips Median	Affected hips IQR	Unaffected hips Median	Unaffected hips IQR	p-value
Extension	20° (15–25)	15–25°	21° (17.5–25)	20–25°	0.5
Flexion	110° (100–115)	99–116°	110° (105–115)	106–115°	0.7
Internal rotation	15° (5–25)	5–25°	15° (15–35)	15–31°	0.2
External rotation	40° (35–45)	34–45°	45° (35–47.5)	36–45°	0.3

Table 2. Association between the variables

A	B	C	D	E	F	G	H	I	J	K	L	M
1	F	13	Left	88/38	–/–	–/–	35	19	80/98	80	3/10	+/–
2	F	[a]	Right	[a]/[a]	[a]/[a]	[a]/[a]	42	21	100/97	100	3/37	–/–
3	F	12	Left	70/59	+/–	–/–	35	23	83/96	83	[a]/[a]	+/–
4	F	11	Right	[a]/[a]	[a]/[a]	[a]/[a]	40	21.1	100/100	100	1/35	–/–
5	F	[a]	Both	96/79	+/–	–/–	41	20	100/100	100	[a]/[a]	–/–
6	M	13	Left	95/110	+/+	+/–	36	22	83/93	83	15/11	+/+
7	F	14	Both	59/84	–/+	+/–	27	26	100/100	100	30/13	–/–
8	F	11	Both	62/72	+/+	–/–	41	21	100/100	100	[a]/[a]	–/–
9	M	18	Right	50/[a]	–/[a]	–/[a]	27	25	100/100	100	3/13	–/–
10	F	10	Right	63/[a]	+/[a]	–/[a]	41	20	90/97	90	1/25	–/–
11	F	11	Both	54/55	+/+	–/–	38	22	88/100	88	[a]/[a]	+/–
12	M	14	Both	83/[a]	+/+	–/[a]	[a]	[a]	99/99	99	16/35	–/–
13	M	12	Left	56/51	–/+	–/–	23	22	100/100	100	[a]/[a]	–/–
14	M	13	Both	103/90	+/+	–/–	[a]	[a]	86/84	86	4/34	+/+
15	M	11	Both	107/[a]	+/[a]	+/[a]	40	21	92/91	92	32/3	–/–
16	F	12	Right	51/95	+/+	–/–	28	23	100/100	100	12/27	–/–
17	M	13	Left	88/[a]	–/[a]	–/–	39	21	73/100	73	18/15	–/–

[a] not possible to evaluated or score.
A Patient no.
B Sex
C Age at operation
D Sick hip
E Alpha angle (Left/Right)
F Labral degeneration (Left/Right)
G Chondrolabral damage (Left/Right)
H SF-36 PCS
I SF-36 MCS
J WOMAC
K Osteoarthritis (Left/Right)
L Preoperative Southwick angle (Left/Right)
M Impingement test (Left/Right)

affected hips (0.2, CI: 0–0.4). Labral degeneration was located anterosuperior in 8 of 11 affected hips (0.7, CI: 0.4–0.1) and posterosuperior in 3 of 11 affected hips (0.3, CI: 0–0.6). Chondrolabral damage was located anterosuperior in 2 of 4 affected hips and posterosuperior in 2 of 4 affected hips.

The median SF-36 physical component score (PCS) was 54 (49–56, CI: 45–56) and the median mental component score (MCS) was 56 (54–58, CI: 55–58). The scores for a cohort with similar age from the Danish population were 56 for the PCS and 56 for the MCS (Bjørner et al. 1997). The median WOMAC score of the affected hips was 99 (87–100, CI: 87–100) and that of the unaffected hips was 100 (97–100, CI: 96–100). ROM was similar between affected and unaffected hips (Table 1). 6 of 24 affected hips (rate = 0.3, CI: 0.01–0.5) had a positive impingement test, as compared to 1 of 10 unaffected hips (0.1, CI: 0–0.3) (Table 2).

Discussion

During the last two decades, it has become increasingly evident that even subtle hip deformities can cause FAI, and thereby osteoarthritis development. SCFE is known to be a precursor of cam deformity, and thereby OA. However, no studies have evaluated the clinical and radiological presentation, including MRI and patient-reported outcome, at long-term follow-up. We therefore asked the following questions: (1) does cam deformity or (2) do labral degeneration, chon-

Table 3. SCFE follow-up studies evaluating CAM deformity, osteoarthritis, and patient-reported outcome

A	B	C	D	E	F	G	H
Zilkens et al.	12 (7–17)	11 (4–20)	47	30 of 38 [a]	35 of 38 [b]	SF-36 PF 86.7 SF-37 RP 78.9	HHS 92, range 60–100
Fraitzl et al.	14 (12–17)	14 (11–21)	16	13 of 16 [a]	[c] [c]	[c]	[c]
Miese et al.	13 (9–15)	12 (4–39)	35	29 of 35 [a]	19 of 175 [d] 44 of 175 [d]	[c]	[c]
Wensaas et al. 2012		37 (21–50)	43	[c] [a]	10 of 43	[c]	HHS 92, range 53–100
Wensaas et al. 2011	13 (11–15)	38 (21–57)	76	[c] [a]	23 of 76	EQ-5D Index 0.84 EQ-5D Visual 74	HHS 88, range 45–100
The current study	12 (10–14)	15 (10–17)	24	15 of 24 14 of 17	1 of 24 11 of 14	SF-36 PCS 54 SF-36 MCS 56	Median WOMAC 100, range 73–100

[a] No MRI performed.
[b] No differentiation between osteoarthritis and pre-osteoarthritis.
[c] Not evaluated.
[d] Measured at 5 places in each hip
A Study
B Age at surgery (range)
C Mean follow-up (range), year
D No. SCFE hips
E No. of patients with Cam deformity after SCFE radiography / MRI
F No. of patients with osteoarthritis/pre-osteoarthritis
G Patient-reported outcome (HRQoL) after SCFE
H Patient-reported joint function outcome after SCFE, HHS Harris Hip Score

drolabral damage, and osteoarthritic development appear at 10–17 years of follow-up after fixation of SCFE; and (3) is the clinical and patient-reported outcome affected?

Our study had several limitations. Firstly, it was a small study cohort of 17 patients and 24 affected hips, which limit general conclusions. However, our database searches ensured that all patients eligible for inclusion were invited, reducing the potential for selection bias. Secondly, clinical follow-up was performed by 2 authors, 1 at each center. This could, as a result of interobserver variability, have biased the results at follow-up. However, the radiographic evaluations were performed by single observers only, thus eliminating interobserver variability. Thirdly, although 10- to 17-year follow-up is considered long-term in classical hip surgery, this may not be so in the context of development of degenerative joint disease. Thus, our follow-up cannot be considered final, and further degenerative joint disease can be anticipated.

On both standard AP pelvic radiographs and MRI, we found that most hips had signs of cam-type structural hip deformity. On MRI, the measured pathological alpha angles revealed a wide range of reduced femoral head/neck offset and cam deformity. Furthermore, all alpha angles were above the suggested normal value of 42° (Nötzli et al. 2002, Beaule et al. 2005, Miese et al. 2010). In agreement with our findings, on plain AP radiographs Zilkens et al. (2011), Fraitzl et al. (2007), and Wensaas et al. (2012) found a reduced head/neck offset in most patients after SCFE.

Only 1 previous study (Table 3) has evaluated the consequences of SCFE by MRI (Miese et al. 2010). We found a wide range of increased alpha angles and mainly an anterosuperior localization of labral degeneration and chondrolabral damage. These findings are similar to the observations by Miese et al. in their MRI study of 26 patients (35 hips) 12 years after SCFE. Furthermore, the anterosuperior localization of degenerative changes is reported in several studies on hips with cam-type deformity (Leunig et al. 2000, 2009, Ganz et al. 2008, Reichenbach et al. 2011). In their cross-sectional MRI study of asymptomatic young men, Reichenbach et al. (2010) found cam deformity, cartilage damage, and labral degeneration in the same location, the anterosuperior quadrant of the acetabulum. Similar to what we found, Miese et al. (2010) found preosteoarthritic changes on T2-weighted MRI in 33 patients 12 years after SCFE. Like us, they did not find any relationship between preosteoarthritic changes and the clinical presentation. In agreement with our findings, Zilkens et al. (2011) found no signs of osteoarthritis on plain AP radiographs at follow-up of 38 patients 11 years after SCFE. Wensaas et al. (2012) found OA in 10 of 43 SCFE hips 37 years after SCFE. The high prevalence of anterosuperior pre-osteoarthritic changes and reduced head/neck offset found in this young patient group adds to the hypothesis that SCFE results in cam-type deformity and FAI (Beck et al. 2005, Ganz et al. 2008, Jessel et al. 2009, Leunig et al. 2009, Barros et al. 2010, Klit et al. 2011).

The patient-reported HRQoL and hip-specific outcome (SF-36 and WOMAC questionnaires) did not reveal any signs of hip symptoms or functional compromise. These findings are consistent with the literature, in which symptomatic joint degeneration resulting from cam-type deformity normally does not develop until the fifth decade of life (Stulberg et al. 1975, Boyer et al. 1981, Beck et al. 2005, Wei et al. 2011, Wensaas et al. 2011, 2012). However, Zilkens et al. (2011) found decreased SF-36 scores but only for the subscale parameters of physical function and role physical. While 2 studies (Southwick 1967, Mamisch et al. 2009) have shown that patients with SCFE have reduced ROM, especially in internal rotation and flexion, our patients had normal ROM. However, reduced ROM correlates with the degree of slip (Southwick 1967, Tönnis 1976, Loder et al. 2006, Fraitzl et al. 2007, Mamisch et al. 2009), and our patients all had mild or moderate slip. We observed that a positive impingement test was more frequent in affected hips than in unaffected hips, thus indicating at least some joint affection.

In conclusion, our observations support the emerging consensus that SCFE is a precursor of cam deformity, FAI, and joint degeneration.

Study idea and design: KG, KS, and AT. Collection of data: JK, KG, EM, JG, and AT. Analysis and/or interpretation of data: all authors. Writing of draft manuscript: JK, AT, and TK. Editing and approval of manuscript: all authors.

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No competing interests declared.

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