Early osteoarthritis after slipped capital femoral epiphysis

Cartilage degeneration, residual deformity and patient-reported outcome in 25 patients

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Background and purpose — Slipped capital femoral epiphysis (SCFE) results in a more or less pronounced deformity of the proximal femur, sometimes causing impingement and early osteoarthritis. We studied early osteoarthritis after SCFE and the association with deformity and self-reported hip function, pain, and quality of life.

Patients and methods — 9 women and 16 men, mean age 32 (21–50) years, 19 with unilateral and 6 with bilateral SCFE, participated. All patients had primarily been operated by pin or screw with no attempt at reposition of the slip. Hips were examined by delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC), which quantifies and locates cartilage degeneration. Plain radiographs were used to measure deformity as determined by the alpha angle. Outcome was assessed by Oxford hip score, Hip Groin Outcome score and EQ-5D-Visual scale.

Results — In the 19 unilateral SCFE, on the slip side dGEMRIC mean value was 533 ms (SD 112, range 357–649) versus mean 589 ms (SD 125, range 320–788) on the non-slip side, (p = 0.01). The dGEMRIC correlated negatively to the alpha angle, correlation coefficient (CC) = –0.60, (p = 0.002). Oxford hip score, pain, and EQ-5D-Visual scale correlated to dGEMRIC CC = 0.43 (p = 0.03), CC = 0.40 (p = 0.05), and CC = 0.49 (p = 0.01) respectively.

Interpretation — After SCFE, even relatively mild residual hip deformity can be associated with cartilage degeneration. A high alpha angle was associated with worse cartilage status. The Oxford hip score identified symptoms even though our patients had not previously sought medical care after the index operation. Quality of life showed strong inverse correlation with cartilage degeneration. Objective assessment of early cartilage degeneration may be useful for treatment decisions and follow-up.

Slipped capital femoral epiphysis (SCFE) results in a more or less pronounced deformity of the hip joint. Severe slips presumably pose a higher risk of early osteoarthritis (OA) (Hagglund et al. 1988, Loder et al. 2006, Rahme et al. 2006)

The goal when treating SCFE is to prevent further slip by stabilizing the epiphysis. This can be done with a smooth pin with a hook device or a short threaded screw to allow further growth and remodeling, or with a threaded screw with compression to close the physis (Hansson 1982, Aronsson et al. 2006). The long-term goal is to achieve congruent hip joints that function painlessly at a high level without subsequent OA.

For severe deformities, secondary surgical treatment has become more common (Azegami et al. 2013). Open surgery with dislocation of the hip, or arthroscopic surgery, can be performed to remove any bony prominences that cause impingement. Additional surgical options aim to re-orient the femoral head to avoid impingement and provide better congruity of the hip joint. Some of these procedures are extensive and entail high complication risks (Azegami et al. 2013).

Sensitive diagnostic tools are needed to identify early cartilage degeneration after SCFE, both in the natural course of the disease and as indication for and evaluation of surgical treatment. Delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) has been used since the late 1990s to study the glycosaminoglycan (GAG) content of articular cartilage (Bittersohl et al. 2015, Zilkens et al. 2015). Low cartilage GAG content results in a low T1 signal within the cartilage, (referred to as the dGEMRIC value), indicating degeneration (Bashir et al. 1996, van Tiel et al. 2016). Several studies of the hip and knee have reported early signs of cartilage degeneration before radiographic changes occur (Tiderius et al. 2007, Zilkens et al. 2011b). In addition, dGEMRIC has shown a correlation with clinically relevant parameters, such as pain and function (Kim et al. 2003).

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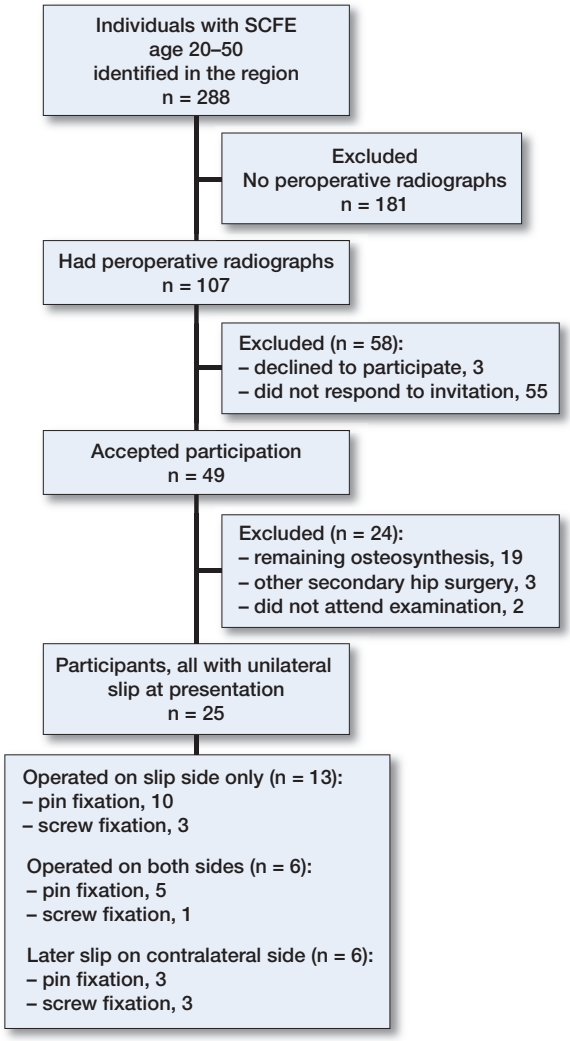

Figure 1. Recruitment and treatment of the 25 subjects with SCFE.

It appears that the deformity arising from SCFE influences the risk of subsequent OA; however, few studies have addressed the subject (Castaneda et al. 2013). We wanted to use dGEMRIC to detect signs of early OA, since the symptoms of early cartilage degeneration are vague and conventional radiographs do not identify early cartilage changes.

We studied the development of early osteoarthritis after SCFE and possible associations between deformity (degree of slip) and self-reported hip function, pain, and quality of life. Our hypotheses were:

1, After SCFE there is development of early osteoarthritis associated with the degree of remaining deformity.

2, Self-reported hip function, pain, and quality of life are associated with early signs of osteoarthritis after SCFE.

We hoped to identify prognostic variables that would enable development of rational treatment plans to improve the long-term outcome after SCFE.

Patients and methods

Participants

Individuals in Västra Götalandregionen previously diagnosed with and treated surgically for SCFE were identified through medical records and Sweden's National Patient Register. Inclusion criteria were SCFE, skeletal maturity, peroperative radiographs available, and no remaining pin or screw fixation. Exclusion criteria were other injuries or diseases affecting the hip or lower extremity, and subsequent surgical procedure other than pin removal. Those between 20 and 50 years of age received a letter with information about the study and an invitation to participate. From the medical records, data on sex, age, symptoms, side of involvement, and radiographic confirmation of a slip were recorded.

25 subjects, mean age 32 (21–50) years (9 women) participated (Figure 1). Follow-up time from initial diagnosis was mean 19 (11–35) years. At initial presentation in childhood all were unilateral SCFE and were treated with Hansson pin or short threaded screw fixation. Prophylactic fixation was performed in 6 patients at the initial surgery on the non-slip side. 6 others later developed a contralateral slip, which was operatively treated (Figure 1). In summary, there were 19 unilateral and 6 bilateral SCFE.

Cartilage quality assessment

dGEMRIC, a magnetic resonance imaging technique with contrast enhancement, was performed on a 1.5 Tesla MRI system (Siemens Aera, Erlangen, Germany) with a body array coil (Body 18). Participants were given gadolinium contrast i.v. (Magnevist 0.5 mmol/mL, Bayer Pharmaceuticals, Berlin, Germany) at a dose of 0.4 mL per kilogram body weight. After the injection, the participants walked for 15 minutes, then waited seated for another 45 minutes. During this time they answered the questionnaires and had conventional hip radiographs. MRI imaging was thus performed 1 hour after contrast injections based on previous results of contrast agent diffusion into hip joint cartilage (Tiderius et al. 2007).

The dGEMRIC protocol included a post-contrast 3D T1-weighted gradient echo sequence with 2 flip-angles and a built-in B1 correction (3D VFA). A coronal projection including both hips with feet in neutral position was performed with the following parameters: TR 15.00 milliseconds (ms), TE 4.77 ms, flip angles 5º and 26º, FoV 320x320 mm, matrix 352x352, slice thickness 0.9 mm, 1 excitation, bandwidth 140Hz/Px, and scan time 9.35 min. MapIt software (Siemens, Erlangen, Germany) was used to calculate T1 values expressed in ms in cartilage regions of interest (ROI) on a workstation with Syngovia software (Syngovia Version B10B, Siemens, Erlangen, Germany). 3 ROIs for each hip were drawn manually on the coronal images, centrally, dorsally, and ventrally spaced 3.6 mm apart (Figure 2). The most cranial part of the cartilage on both the acetabular and the femoral side was included in the ROI, and the lateral border was the basis of the labrum and the

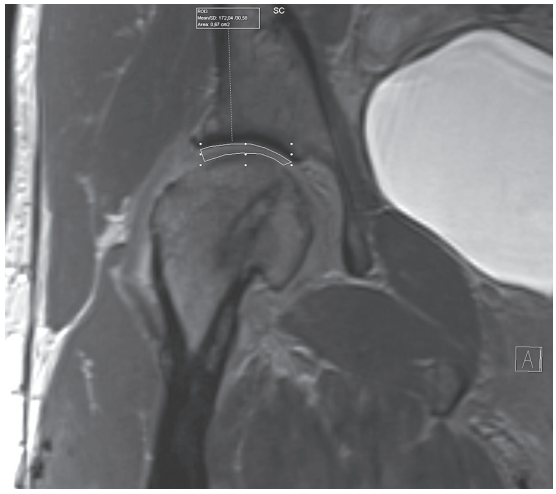

Figure 2. T1 region of interest (ROI) drawn on the initial, T1-gradient echo image, including the central cartilage.

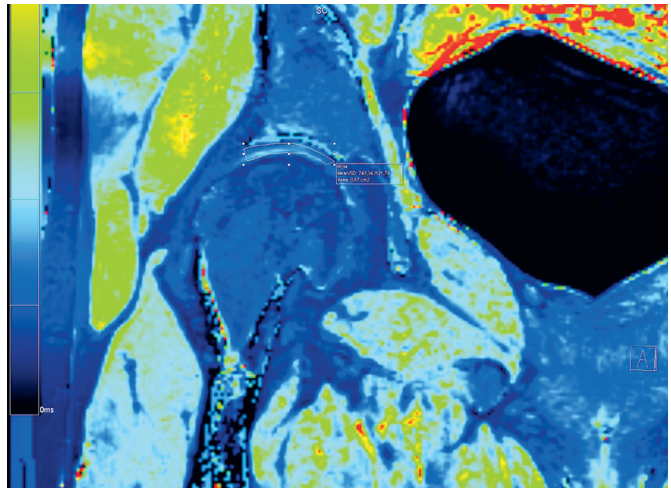

Figure 3. dGEMRIC region of interest (ROI). The same ROI as in Fgure 2, with the corresponding dGEMRIC image.

medial border was the central fovea of the acetabulum. The ROI was drawn on the initial T1-gradient echo image that had the best anatomical delineation and automatically copied to the corresponding color-coded dGEMRIC image including an ROI of the cartilage (Figure 3). The dGEMRIC T1 value was given as mean (1 SD) by the Syngovia software for each area assessed. Remaining metal implants from previous operations was an exclusion criterion in this study to avoid unpredictable influence from artefacts.

All magnetic resonance images were assessed by consensus readings by 2 radiologists (YA and PKJ) blinded to all other data. 10 randomly selected cases were assessed a second time 3 months later, also in consensus readings, to evaluate the reliability of the measurements.

Radiographs to assess deformity

Deformity of the proximal femur was assessed with conventional radiographs obtained at the same visit as the dGEMRIC measurement, using the lateral projection according to Dunn (Meyer et al. 2006). The alpha angle describes the sphericity of the femoral head and reveals possible impingement (Notzli et al. 2002). Alpha angles were classed thus: normal sphericity (< 50 degrees), mild deformity (50–60 degrees), and severe deformity (> 60 degrees) (Zilkens et al. 2011a).

The head shaft angle (HSA) according to Southwick quantifies the posterior slip and was used to subgroup the 50 hips into: mild slip (HSA < 30 degrees), moderate (HSA 30–60 degrees), and severe (has > 60 degrees) (Southwick 1967).

Patient-reported hip function, pain, and quality of life

Hip function was measured with the widely used, disease-specific, validated Oxford Hip Score (OHS), which includes 12 questions graded from 1 to 5 (Dawson et al. 1996). The Copenhagen hip and groin outcome score (HAGOS), developed to assess long-standing hip and/or groin pain in physically active young to middle-aged patients, has also been used to study femoral-acetabular impingement (Thorborg et al. 2011). HAGOS covers 6 dimensions: symptoms (e.g., clicking, paresthesia, difficulties taking a long step), pain, function in daily living, sports and recreation, physical activities, and hip-related effects on quality of life. The score ranges from worst to best, 0–100.

We also used the EQ-5D Visual Analogue Scale (EQ-5D-VAS), a standardized measure of health, which records self-rated health on a 20-cm vertical scale with endpoints labelled “the best health you can imagine” and “the worst health you can imagine” (EuroQol 1990).

Statistics

In the 6 patients with bilateral SCFE, we selected the more severely deformed hip (higher alpha angle), for the comparative analysis.

The dGEMRIC values and alpha angles were normally distributed and a paired sample t-test was used. Non-parametric statistical calculations were used for the remaining analysis since the clinical outcome measures were scale data. Correlations were analyzed using the Spearman rank correlation. All tests were 2-tailed and statistical significance was set at $p < 0.05$. The data were analyzed using SPSS Statistics version 22 (IBM Corp, Armonk, NY, USA).

Ethics, funding, and potential conflicts of interest

The study was approved by the Human Research Ethics Committee of the Medical Faculty at the University of Gothenburg, Sweden (Dnr 904-13), in accordance with the ethical standards of the Helsinki Declaration.

Funding was received from the state hospital research unit and orthopaedic department. The authors declare no conflicts of interest.

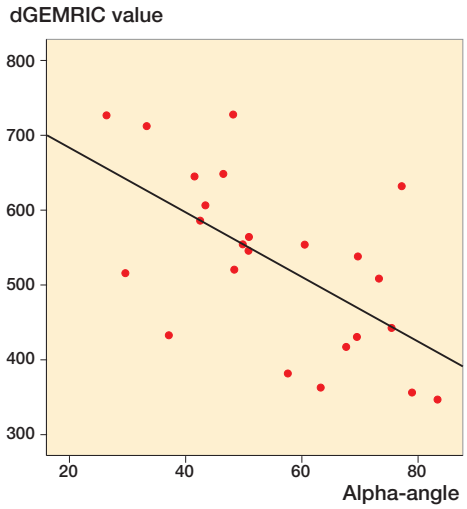

Figure 4. Scatter plot of alpha angle and dGEMRIC value (ms). The mean dGEMRIC value (ms) of the three regions—ventral, central, and dorsal—on the slip side in 19 subjects with unilateral SCFE and the most deformed side in 6 subjects with bilateral SCFE. n = 25.

Results

Cartilage quality assessment

The reliability testing of the dGEMRIC measurements revealed excellent interclass correlation coefficients for the 3 regions of interest measured by the 2 observers (YA and PKJ). In the ventral region ICC was 0.98 (95% CI 0.95–0.99), in the central region ICC was 0.96 (CI 0.90–0.98), and in the dorsal region ICC was 0.99 (CI 0.97–0.99).

As there were no statistically significant differences in dGEMRIC values for the ventral, central, and dorsal regions of the hip joints, we calculated the mean of the 3 regions for each hip.

In the compiled group of 25 hips (19 unilateral slips and the 6 most severe slips in the bilateral group) the mean dGEMRIC value was 532 ms (SD 114, range 347–728). When analyzing the 19 patients with unilateral SCFE we found a significant difference (p = 0.01) in dGEMRIC value comparing the slip side, mean 533 ms (SD 112, range 357–649) with the non-slip side, mean 589 ms (SD 125, range 320–788).

For the dGEMRIC correlated (Spearman rank correlation) to the alpha angle, correlation coefficient (CC) = –0.60 (p = 0.002), meaning that the higher the alpha angle or the worse the deformity, the lower was the dGEMRIC value, equivalent to cartilage injury/degeneration (Figure 4).

Radiographs to assess deformity

The degree of deformity of the proximal femur was assessed at follow-up on plain radiographs on both sides, corresponding to 50 hips (31 hips with SCFE and 19 judged as normal). The deformity was relatively mild, with a mean alpha angle of 54 (24–83) degrees on the slip side (31 hips) (Table 1). For the alpha angle correlated (Spearman rank correlation) with the HSA, CC = 0.50 (p < 0.001).

In the 19 patients with unilateral SCFE, we found a mean alpha angle of 54 (30–79) degrees on the slip side and 45 (37–62) on the non-slip side (p = 0.01). The difference in HSA, 16 versus 10 degrees, was not significant (p = 0.09).

Table 1. Degree of deformity of the proximal femur at follow-up with measurements of alpha angle and head shaft angle

	Slip hips n = 31	Non-slip hips n = 19
Alpha angle:		
< 50° (normal)	14	15
50–60° (mild)	5	2
> 60° (severe)	12	2
Head shaft angle:		
Mild	27	19
Moderate	4	–
Severe	–	–

Table 2. Results from the 3 questionnaires, Oxford Hip Score, HAGOS, and the EQ-5D Visual Scale, and correlation with the dGEMRIC values for the 25 subjects

	Descriptive statistics			Correlation with dGEMRIC values	
	median	range	IOR	coefficient	p-value
Oxford Hip Score	46	36–48	43–48	0.43	0.03
HAGOS pain	92	50–100	84–100	0.40	0.05
HAGOS symptom	88	54–100	73–100	0.30	0.1
HAGOS ADL	100	50–100	82–100	0.36	0.08
HAGOS Sport/Rec	94	50–100	78–100	0.34	0.09
HAGOS PA	88	50–100	75–100	0.36	0.08
HAGOS QOL	85	40–100	65–100	0.38	0.06
EQ-5D VAS	90	50–100	70–97	0.49	0.01

IOR: 25th to 75th percentile

Patient-reported hip function, pain, and quality of life

There was an association between both hip function and overall quality of life and cartilage degeneration. Oxford hip score, pain, and EQ-5D-VAS correlated with dGEMRIC CC = 0.43 (p = 0.03), CC = 0.40 (p = 0.05), and CC = 0.49 (p = 0.01), respectively (Table 2).

Discussion

We found cartilage degeneration on the slip side after SCFE even in cases with relatively mild deformity. A high alpha angle, i.e., femoral-acetabular impingement, was strongly associated with signs of cartilage degeneration Patient-reported hip function and quality of life were inversely associated with signs of early osteoarthritis.

Cartilage quality assessment

The quality of the cartilage did not differ between the ventral, central, and dorsal region in the individual hips, which was surprising since we had expected cartilage changes as a consequence of femoral-acetabular impingement anteriorly.

Both the dGEMRIC values and the alpha angles on the slip side revealed less pronounced changes in our patients (mean age 32 years) than in a previous study, where the mean age was 23 years (Zilkens et al. 2011a).

In a group of patients with femoral-acetabular impingement who underwent hip arthroscopy (Chandrasekaran et al. 2015), the mean preoperative dGEMRIC value was 426 ms, as opposed to 532 ms in our study group.

Kim et al. (2003) used dGEMRIC to study 37-year-olds with non-dysplastic and non-symptomatic hips, and considered values of 570 (SD 90) ms as normal. Any value more than 2 SD lower (< 390 ms) was defined as OA (Kim et al. 2003). Their study aimed to predict outcome after pelvic osteotomy for hip dysplasia, and they found a steeply increased risk for failure in patients with values below 390 ms. Cunningham et al. (2006) arrived at a similar cut-off of 370 (SD 88) ms predicting failure and 498 ± 105 ms for satisfactory results (Cunningham et al. 2006). In our study, 5 of the total 31 slip hips had a dGEMRIC value below 390 ms.

Even though we found a statistically significant difference between the slip and non-slip side in patients with unilateral slip, dGEMRIC values displayed high inter-individual variation between sides. This could reflect the different degrees of slip between patients, but possibly also differences in physical activity, which has been reported to influence dGEMRIC values (Roos and Dahlberg 2005). By scanning both hips simultaneously, we eliminated an important methodological issue, i.e., the risk of ongoing contrast medium diffusion in between scanning of separate hips (Tiderius 2007).

Considering the variability within subjects it is possible that the dGEMRIC method might be most useful to follow progression within the same patient rather than between patients.

We found a relatively high correlation between deformity as assessed from the alpha angle, and dGEMRIC measurements. Both Carney et al. (1991) and Jerre (1950) stated that the remaining deformity, referring to the degree of slip measured with the HSA, predisposes to early OA. The exact mechanism underlying OA development in the hip joint is not known; OA arising through a femoral-acetabular impingement mechanism might have another course than that acting in patients with a more pronounced deformity directly related to the degree of slip. Are the slip deformity and the alpha-angle deformity 2 different assessments describing different pathologies? Which pathology develops into a "whole joint disease"?

Radiographs to assess deformity

We noted mean alpha angle of 54 degrees on the slip side, whereas Zilkens et al. (2011a) reported this to be 65, which implies that our study group had relatively mild deformities. Even so, we observed a clear difference in alpha angle comparing the slip and non-slip side in the 19 patients with unilateral SCFE.

We used the lateral head shaft angle according to Southwick to assess the degree of slip; however, a previous reliability study revealed that a change of 12 degrees was necessary before observer variability could be ruled out (Carney and Liljenquist 2005). In addition, the reproducibility of the Lauenstein projection was low, which became clear when we assessed the primary radiographs at the time of presentation in childhood, and we observed marked variations in the degree of flexion, abduction, and rotation. Therefore, we could not rely on comparisons between the initial deformity and that at long-term follow-up.

Regarding the relatively mild deformity at this long-term follow-up, it should be noted that all hips had deliberately been treated with smooth pins or short threaded screws to allow for further growth. Both longitudinal growth and remodeling can be expected to have occurred (Holmdahl et al. 2016, Ortegren et al. 2016).

Patient-reported hip function, pain, and quality of life

We found a correlation between cartilage quality and hip-specific reported outcome including function, OHS, and HAGOS, as well as a correlation with the EQ-5D-VAS, reflecting quality of life. Even comparatively small differences in alpha angle and dGEMRIC value influenced the patient-reported outcome after SCFE, a finding we have not seen so clearly illustrated before. Previous studies have mainly been performed on patients with ongoing symptoms seeking medical care and the threshold for when to expect symptoms related to morphological changes remains unknown (Chandrasekaran et al. 2015, Sansone et al. 2016). Our study group of relatively young patients showed subtle changes in dGEMRIC values and mild deformity after SCFE. We do not know if these patients' expectations regarding what is normal in terms of activity and ability to participate in sports differ from those of older populations with confirmed OA or the young elite athletes on whom these patient-reported outcome measures have been used before (Sansone et al. 2016).

Sansone et al. (2016) studied 75 patients with femoral-acetabular impingement 2 years after arthroscopic treatment, and reported improvement according to the HAGOS questionnaire and also in the EQ-5D.

Chandrasekaran et al. (2015) studied patients undergoing hip arthroscopy, 1 group with dGEMRIC value below and one above 323, i.e., 1 SD below the cohort mean of 426 ms. While both groups had significantly improved Harris Hip Scores 2 years after arthroscopy, the group with dGEMRIC value above the cut-off 323 ms also showed improvement in the Hip Outcome Score Activities for ADL, Sport-specific Subscale, and the visual analogue scale for pain (Chandrasekaran et al. 2015). In our study, no participant had a dGEMRIC value under 323 ms. The lowest value was 347 ms. However, longer

follow-up might reveal progression of OA and clinical manifestations (Zilkens et al. 2011a).

The correlation between the dGEMRIC and EQ-5D results was quite unexpected. We can only speculate that these patients, who had not previously sought contact with the medical care system for symptoms, nonetheless reported lower quality of life due to problems related to their previous SCFE. It is worth noting that the EQ-5D-VAS was the last questionnaire the participants completed, which might have motivated them to report some adverse effect of their SCFE.

We found no previous publication testing HAGOS or OHS in SCFE, but in a study that used HAGOS on patients with hip dysplasia, the patients scored lower than controls on every dimension (Jacobsen et al. 2013). According to Impellizzeri et al. (2015) OHS can also be used to assess femoral-acetabular impingement.

Limitations

Physical activity has been suggested to influence dGEMRIC measurements, possibly owing to cartilage adapting to increased mechanical demands (Roos and Dahlberg 2005). We had no data on the physical activity of our participants, which is a limitation. The number of participants is relatively small, and we lacked information on the initial degree of slip. More comprehensive assessment of the orientation of the impingement/alpha angle, with MRI or CT scanning, could have been advantageous.

Summary

With even relatively mild residual deformity, a high alpha angle after SCFE can be associated with cartilage degeneration. Symptoms that are too small to prompt patients to contact the health care facilities can nonetheless be identified by the Oxford Hip Score. Quality of life appears strongly and inversely associated with cartilage degeneration.

Objective assessment of early cartilage degeneration may be useful in treatment and follow-up after SCFE.

All authors contributed with the planning, methodology, protocol, data analyses and writing of the manuscript. LH and JR obtained the ethical approval, recruited participants, organized the visit to the radiology department, and collected the data and performed the statistical analysis, as well. YA and PKJ in addition assessed the dGEMRIC images and performed the reliability test.

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